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FOREWORD

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisfied with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the individualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead, we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman
ISIS Project
Tallahassee, Florida

CONTENTS

What's It All About?

In this minicourse, you will learn about why you are you and not someone else.

You'll find out how your characteristics have been affected by your parents, your grandparents, and by ancestors you've never seen or even heard about.

You'll learn about genetics, the study of inheritance. And you'll see how genetics helps us improve both plants and animals.

core
Activity 1 Planning

Activity 2 Page 6

Objective 1: Identify Mendel's contributions to the field of genetics.

Sample Question: Which statements about Mendel are true?

a. He said that heredity is passed on by links in the reproductive cells.
b. He named the generation links "genes."
c. He studied individual traits rather than many traits at one time.
d. He developed hybrids by crossing two pure strain plants having opposite traits.

Objective 2: Describe the difference between a pure strain plant and a hybrid plant.

Sample Question: Match the letter of each plant in List A with one or more descriptions in List B.

List A
a. Pure strain plant
b. Hybrid plant

List B
1. If crossed with a pure strain plant having the opposite trait, all the offspring will be hybrids.
2. Its parents had different genes for a certain trait.
3. If crossed with a plant having identical genes, all offspring will have the same traits as the parents.
4. If crossed with a plant having identical genes, not all offspring will have the same traits as the parents.

Activity 3 Page 16

Objective 3: Tell whether an offspring has dominant or recessive traits.

Sample Question: Two different pure strain plants are crossed. The offspring show the trait of only one parent. What kind of trait does the offspring have?

a. dominant

b. recessive

c. hybrid

Objective 4: Explain how parents pass genes on to their offspring.

Sample Question: When genes for a trait are passed on to offspring

a. each parent contributes a pair of genes.

b. each parent contributes one gene.

c. one parent contributes two genes.

Objective 5: Explain how selective breeding, inbreeding and crossbreeding are done.

Sample Question: In inbreeding, the animals that are mated

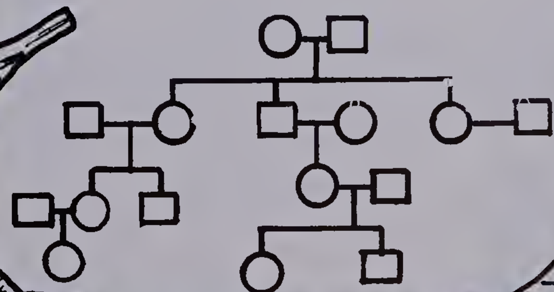
a. are of different breeds.

b. are from the same set of offspring.

c. have been raised by the same breeder.

Objective 6: Interpret a drawing of a family tree.

Sample Question: How many parents are shown in this family tree?



Activity 4 Page 26

Objective 7: Describe the function of the pistil and stamens of a flowering plant.

Sample Question: Match the letter of each flower part in List A with the function in List B.

List A
a. Pistil
b. Stamen

List B
1. Produces pollen
2. Produces seeds
3. Produces eggs

Objective 8: Tell how artificial pollination, cross-pollination, and self-pollination are done.

Sample Question: For artificial pollination,
a. plant breeders do the pollinating.
b. wind carries the pollen.
c. artificial pollen is used.

Objective 9: Describe fertilization in a flowering plant.

Sample Question: During fertilization,
a. a sperm nucleus joins with the egg nucleus.
b. the pollen is carried by the wind.
c. the egg travels upward to meet the sperm.

Objective 10: Tell how to maintain a hybrid strain from generation to generation.

Sample Question: When a hybrid strain has been developed, it may be maintained
a. by self-pollination.
b. from cuttings.
c. from bulbs.

Activity 5 Page 37

Objective 11: Define a mutation.

Sample Question: A mutation occurs when there are

a. *too many recessive genes.*
b. *too many dominant genes.*
c. *changes in a gene.*

Objective 12: Name three methods that can increase mutation rates.

Sample Question: When do mutations occur more often?

a. *when the body is shielded from radiation.*
b. *when certain drugs are used.*
c. *when the temperature of the reproductive cells is lowered.*

Objective 13: Identify the two kinds of body cells in which mutations can be passed on to future generations.

Sample Question: In which body cells can a mutation occur and be passed on to offspring?

a. *brain cell*
b. *blood cell*
c. *egg cell*
d. *sperm cell*

Answers

1. a, c, d 2. a-1, a-3, b-2, b-4 3. a 4. b 5. b 6. 10 7. a-3, b-1 8. a 9. a 10. b, c 11. c 12. b 13. c, d

How Genes Work

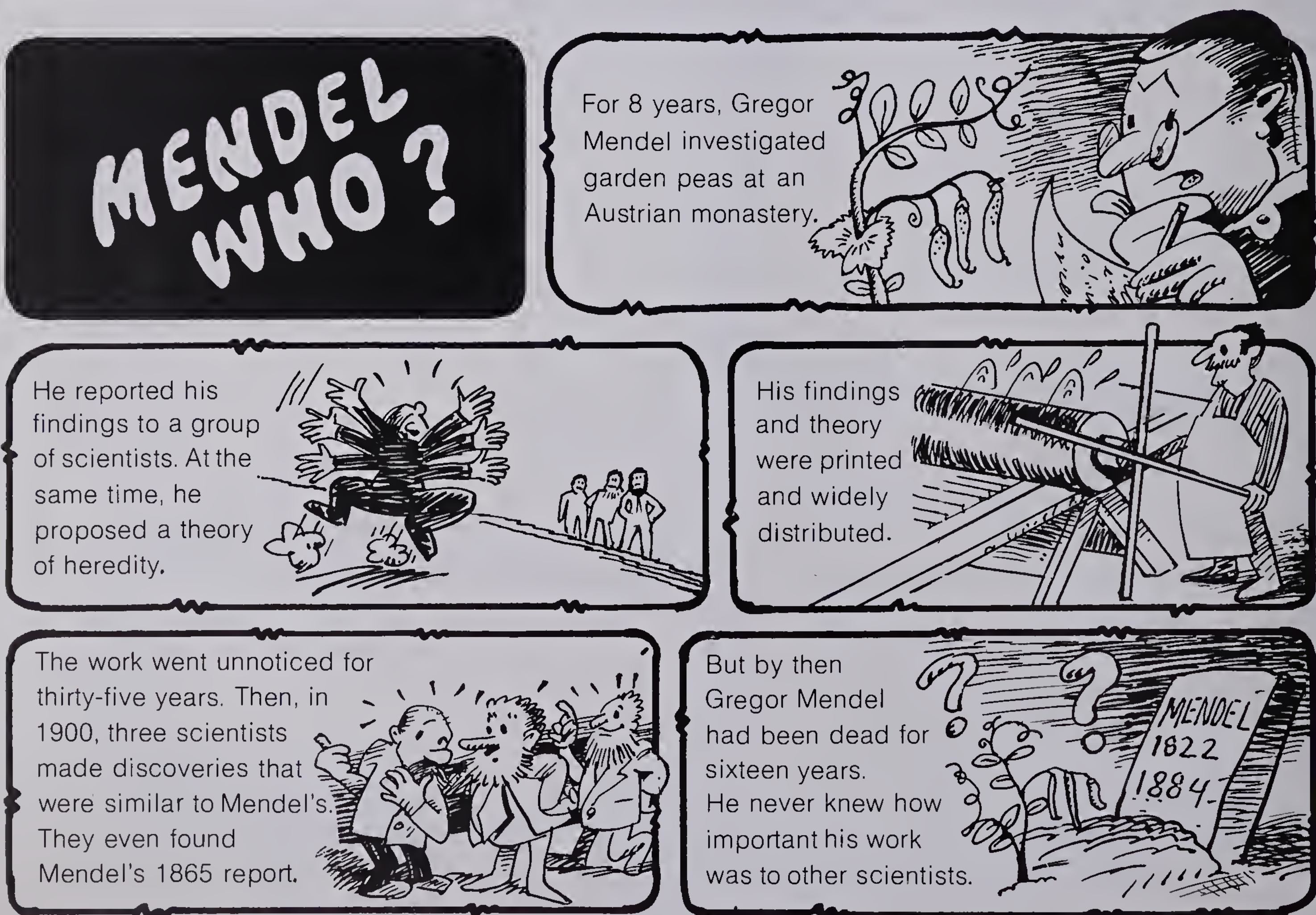
Gregor Mendel (MEN-dal) discovered the generation link! He proposed that heredity is passed on by links in the reproductive cells. Mendel called the links *units* or *elements;* now we call them *genes*. We'll use the term "gene" in this activity.

★ **2–1. What did Mendel call the generation links?**

Mendel thought that there were many genes in the reproductive cells of plants. After all, there were many different traits (characteristics) to control.

Mendel's method of investigation was to study a single trait at a time. Previously, investigators studied all the traits of a plant or an animal at one time.

✔ 2–2. Why was Mendel's method a good one?



One trait that Mendel studied was the height of the pea plant. Some of the plants he worked with were tall, others were short (Figure 2–1). Mendel *cross-pollinated* or *crossed* the pea plants. He took the pollen from one plant and placed it on another plant.

He crossed tall pea plants with other tall pea plants for several generations. And he crossed short pea plants with other short pea plants for several generations. (A *generation* is made up of all the offspring from a crossing.) In this way, Mendel developed a pure strain of tall plants and a pure strain of short plants. (In a *pure strain,* all the offspring are always the same as the parents. For example, pure strain tall pea plants have only tall offspring. Pure strain short pea plants have only short offspring.)

Figure 2–1

✔ 2–3. After several generations, a short plant shows up in a strain of tall plants. What can you say about the strain?

Then Mendel crossed a pure tall plant with a pure short plant (Figure 2–2). He planted seeds from the offspring. All the seeds became tall plants.

Mendel called these offspring *hybrids*. A hybrid is an organism whose parents did not have the same genes for a certain trait.

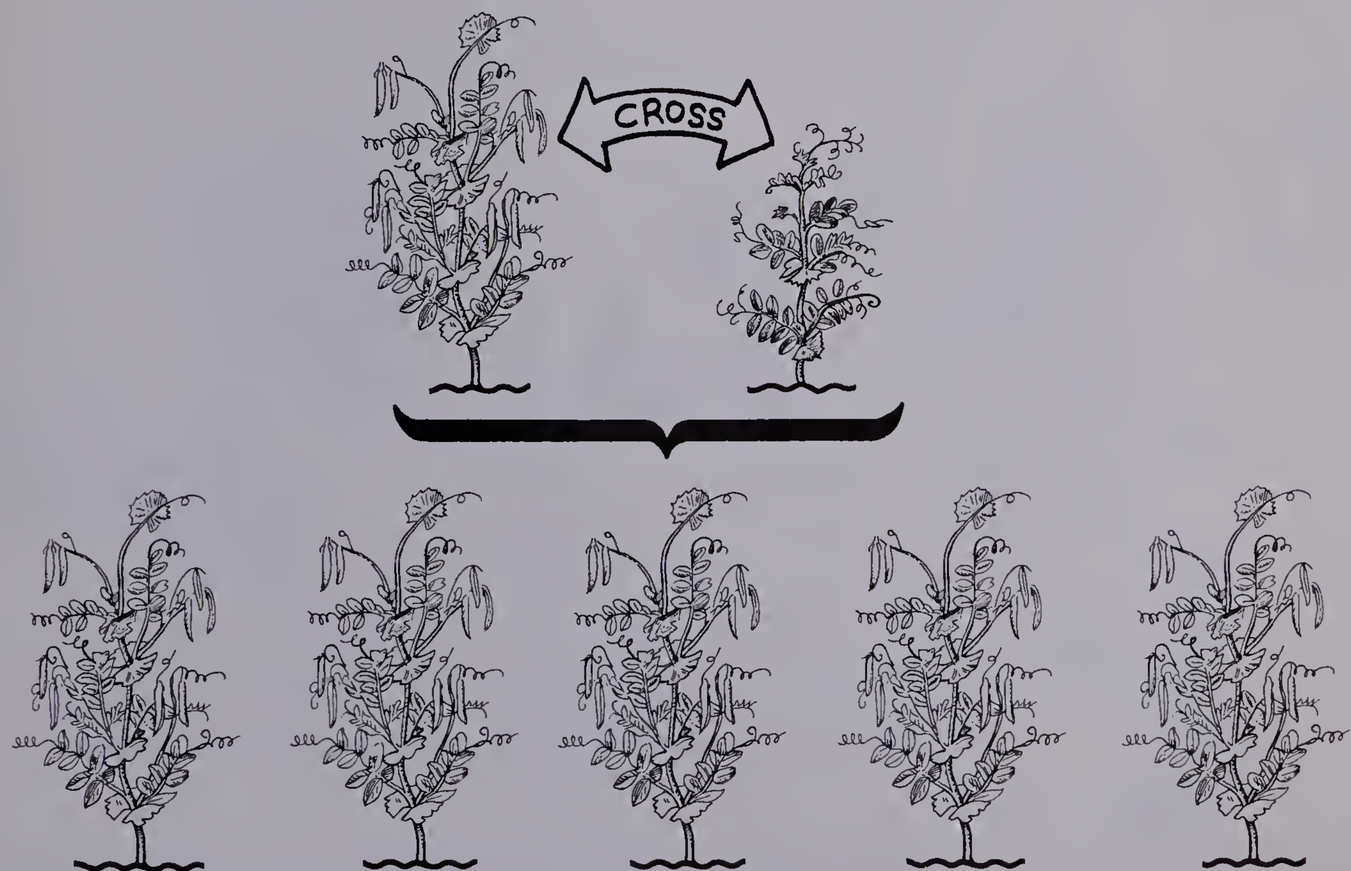


Figure 2–2

Mendel suggested that an offspring inherits one gene from each parent. In a pure-tall pure-short crossing, each offspring inherits a gene for tallness and a gene for shortness. But all the offspring were tall! How could Mendel explain this?

The following activity may help you to understand why the offspring were tall. You will need these materials:

2 pieces of plastic, both the same color
2 pieces of plastic, both colorless or clear

A. The pieces of plastic represent the genes that affect the offspring. Put two colored pieces together; hold them toward the light source; look through them.

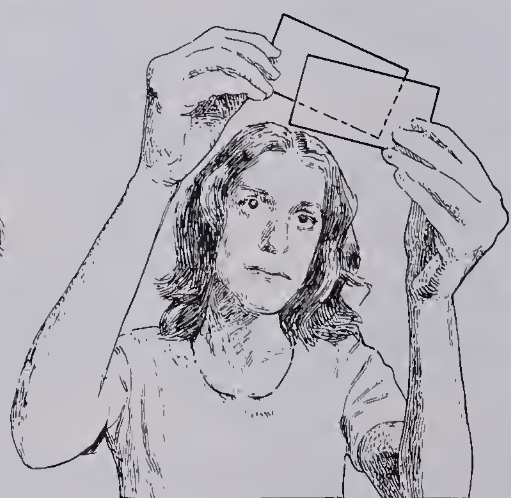
✔ 2–4. Do the combined pieces appear clear or colored?

B. Now put two clear pieces of plastic together. Look through them toward the light source.

✔ 2–5. Do the combined pieces appear clear or colored?

C. Finally, put one colored piece of plastic and one clear piece together. Look through them toward the light source.

✔ 2–6. Do the combined pieces appear clear or colored?



Mendel reasoned that every plant has a pair of genes for each trait. Sometimes the two genes are the same; sometimes they are different. If they are different, one gene may dominate the other. Then one gene is called the *dominant* gene and the other is called the *recessive* gene.

✔ 2–7. Which piece of plastic represents a dominant gene? Which represents a recessive gene?

When Mendel crossed a tall pea plant with a short pea plant, the offspring were all tall. No short plant showed up.

✔ 2–8. In the pea plant, which gene is dominant (the gene for tallness or for shortness)?

After he worked out the idea of dominant and recessive genes, Mendel tested it with pea plants. You may follow the test using these materials:

2 pieces of plastic, both the same color
2 pieces of plastic, both colorless or clear
2 paper bags

A. One paper bag represents a pea plant that is a pure-strain tall parent. The genes for pure strain tallness are alike and dominant. We'll represent them with two pieces of *colored* plastic. Place the colored pieces in the bag.

B. The second paper bag represents a pea plant that is a pure-strain short parent. The genes for pure strain shortness are alike and recessive. We'll represent them with two pieces of *clear* plastic. Place the clear plastic pieces in the bag.

✔ 2–9. One bag has only colored pieces of plastic. The other bag has only clear pieces. What combination will you get when you draw one piece of plastic from each bag?

C. Now take one piece of plastic from each bag. Hold the two pieces together and look through them toward the light source.

✔ 2–10. Do the combined pieces appear clear or colored?

★ **2–11. If you cross a pure-strain tall pea plant with a pure-strain short pea plant, what will the offspring look like? (Tall, short, or medium height?)**

There's a special method to use for predicting which genes an offspring may have. In this method, capital letters represent dominant genes. Small letters represent recessive genes. Remember, every plant has two genes for each trait. When there is a pure strain, the genes are alike. So we write *TT* for a pure tall plant and *tt* for a pure short plant.

Now consider a crossing of a pure-tall pea plant and a pure-short pea plant. Look at the grid (chart) in Figure 2-3. One parent's genes, *TT*, are shown at the top of the grid. The other parent's genes, *tt*, are shown at the left side of the grid. An offspring may have the two genes shown in any box within the grid. Notice that when there's a capital letter and a small letter together, the capital letter is written first.

PURE-TALL PEA PLANT

PURE-SHORT PEA PLANT		*T*	*T*
	t	*Tt*	*Tt*
	t	*Tt*	*Tt*

Figure 2–3

★ **2–12. A pure-strain tall plant is crossed with a pure-strain short plant. What genes will the offspring have? (Use *T* and *t* to describe the combinations.)**

✔ 2–13. Will the offspring be short or tall?

Now let's continue to follow Mendel's investigation. The offspring from the pure-tall pure-short crossing were hybrids. Offspring from a first crossing are called *first generation* offspring. Mendel then crossed the hybrid first generation plants with each other (Figure 2–4). Each parent in the crossing had a dominant gene and a recessive gene *(Tt)*. Predict what the offspring looked like.

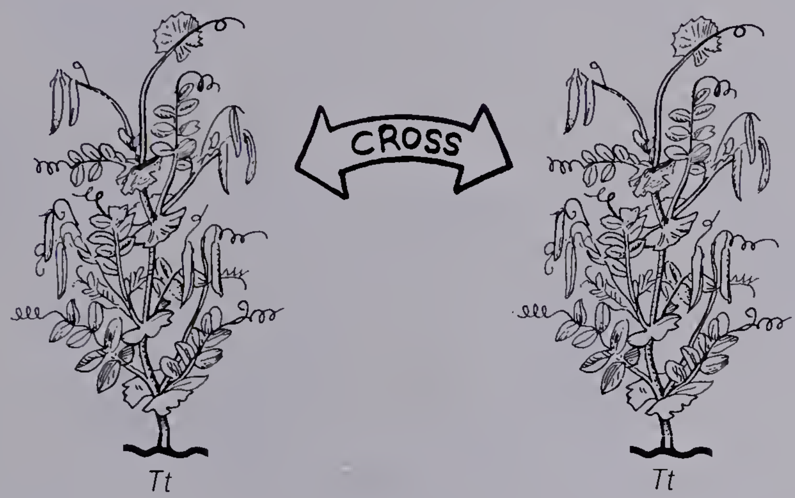
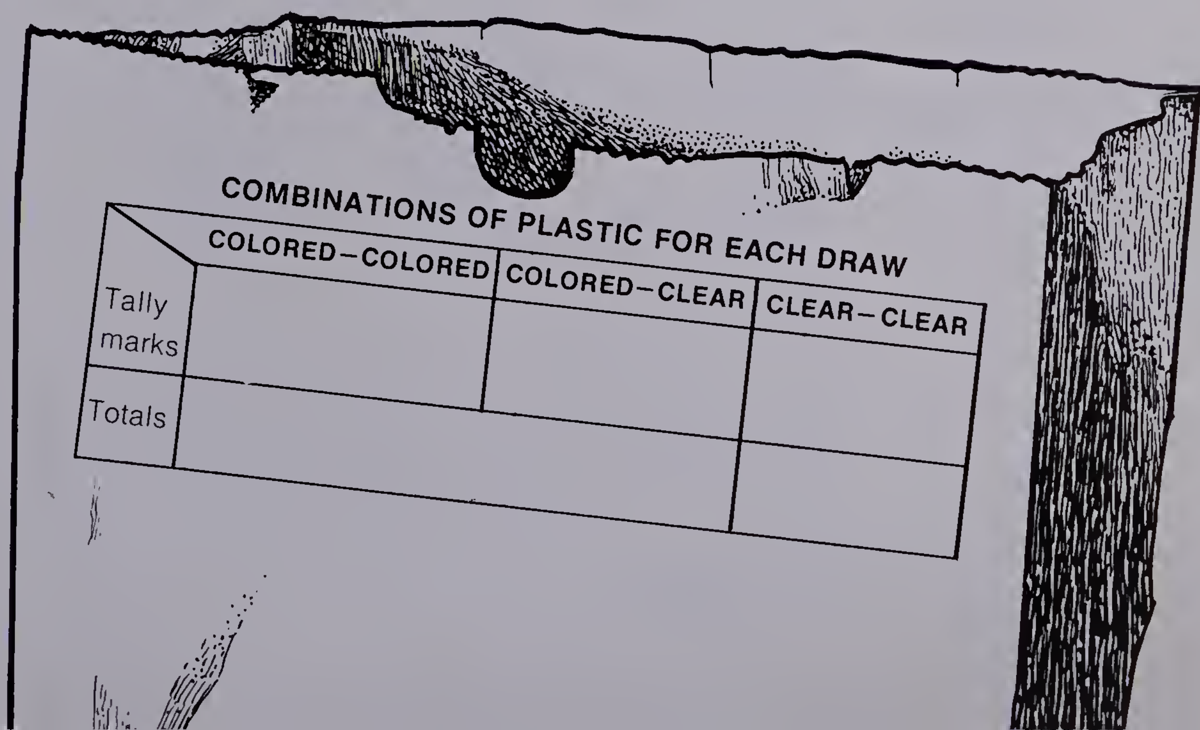


Figure 2–4

There is an investigation that will help you make this prediction. You will need the following materials:

- 2 pieces of plastic, both the same color
- 2 pieces of plastic, both clear or colorless
- 2 paper bags

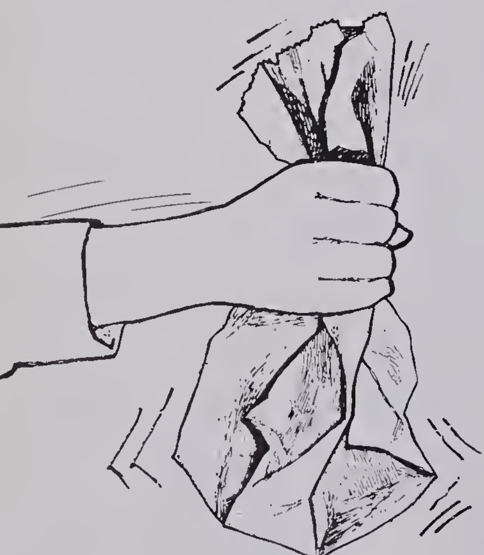
A. Make a table to record your observations. You may want to copy the table shown here. Notice that in this table, the first- and second-column tally marks are to be added together.



COMBINATIONS OF PLASTIC FOR EACH DRAW

	COLORED–COLORED	COLORED–CLEAR	CLEAR–CLEAR
Tally marks			
Totals			

B. Put a colored piece of plastic and a clear piece in each paper bag. Without looking into the bags, draw or take one piece of plastic from each bag. Then look at the two pieces. In your table, find the box for that combination. Record a tally mark in the box.



C. Return each piece of plastic to its original bag. Shake the two bags and draw again. Remember to take one piece of plastic from each bag. Again, write a tally mark in the box for the combination you draw.

Continue this process until you have made 100 draws. Then total the tally marks in the table. Remember to add together the marks for the two different combinations that appear to be colored: Colored-colored and colored-clear. (The marks for these combinations are in the first and second columns of the table shown.)

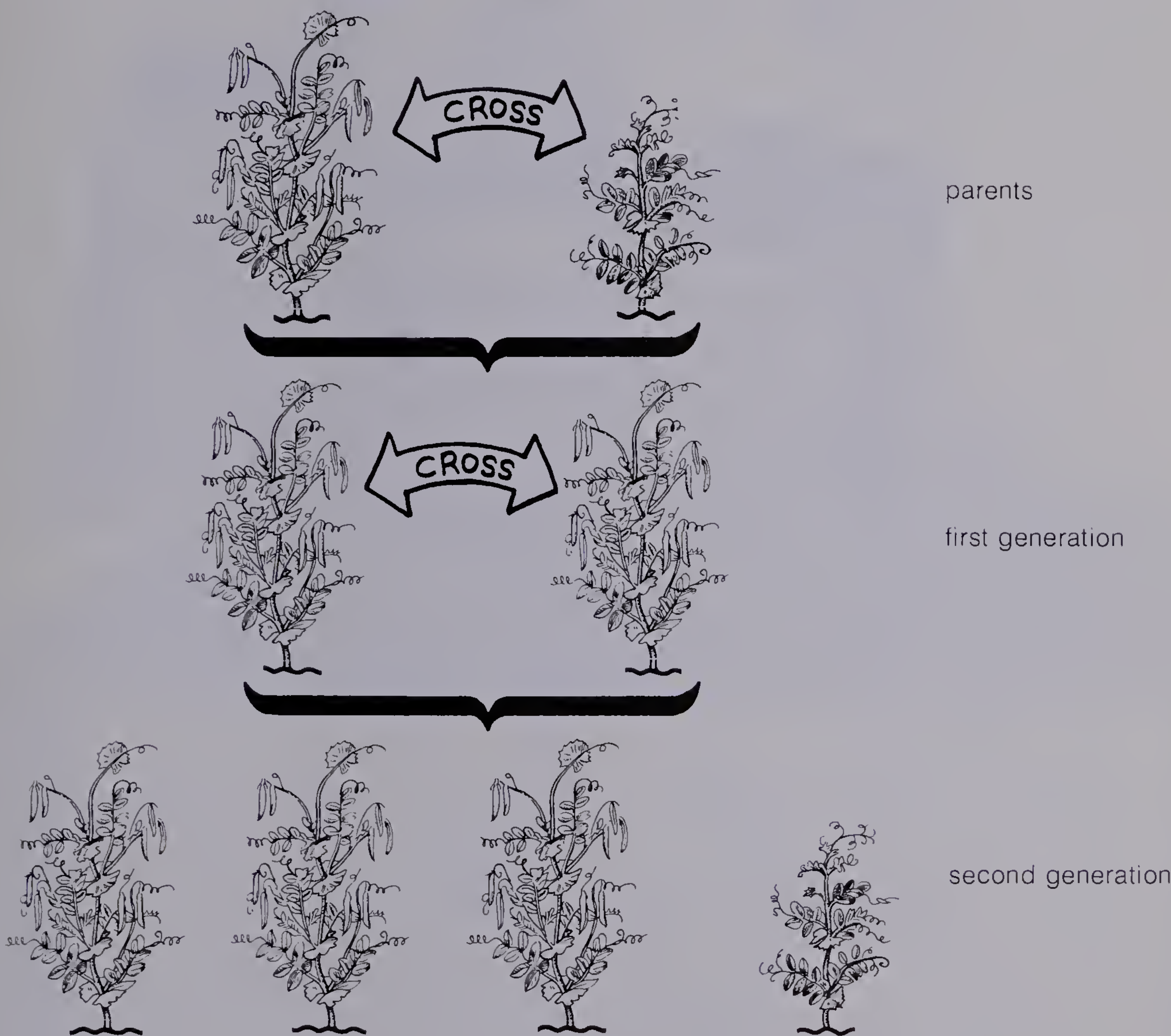
✔ 2–14. What is the total for the colored-colored and the colored-clear combinations?

✔ 2–15. What is the total for the clear-clear combination?

✔ 2–16. Look at your totals for Questions 2–14 and 2–15. Express them as the ratio *combinations that look colored* to *combinations that look clear.* (An example of a ratio is *100 to 50* or *2 to 1.*)

2–17. Use your results from the plastic investigation to predict the appearance of the offspring from two hybrid-tall pea plants. Express your answer in the ratio *tallness to shortness*. The ratio should be in simplest form. (For example, *9 to 3* should be expressed as *3 to 1*.)

When Mendel crossed hybrid tall plants, there were about three tall offspring to each short one. The ratio was about 3 to 1. The greater the number of offspring, the closer the actual count came to 3 to 1.



The draws you made from the two paper bags were affected by chance. It is possible (but not likely) to get the clear-clear combinations 100 times. In fact, it is possible (but not likely) to draw any one of the combinations 100 times. So, you may not have gotten "3 to 1" as an answer to Question 2–16.

PAPER BAG 1

PAPER BAG 2	C	c
C	CC	Cc
c	Cc	cc

Figure 2–5

Look at the grid in Figure 2–5. In your investigation, each paper bag had a colored piece of plastic *C*, and a clear piece *c*. Each time you drew, you could have gotten one of these combinations: *CC*,*Cc*, *Cc*, or cc. Three of the combinations, *CC*, *Cc*, *Cc* appear colored. One, cc, appears clear. So, each time you drew there was a 3 to 1 chance that you'd get a colored combination.

★ **2–18. Draw a grid to show the crossing of two first-generation hybrid tall pea plants. (See Figure 2–6.) Then fill in the squares.**

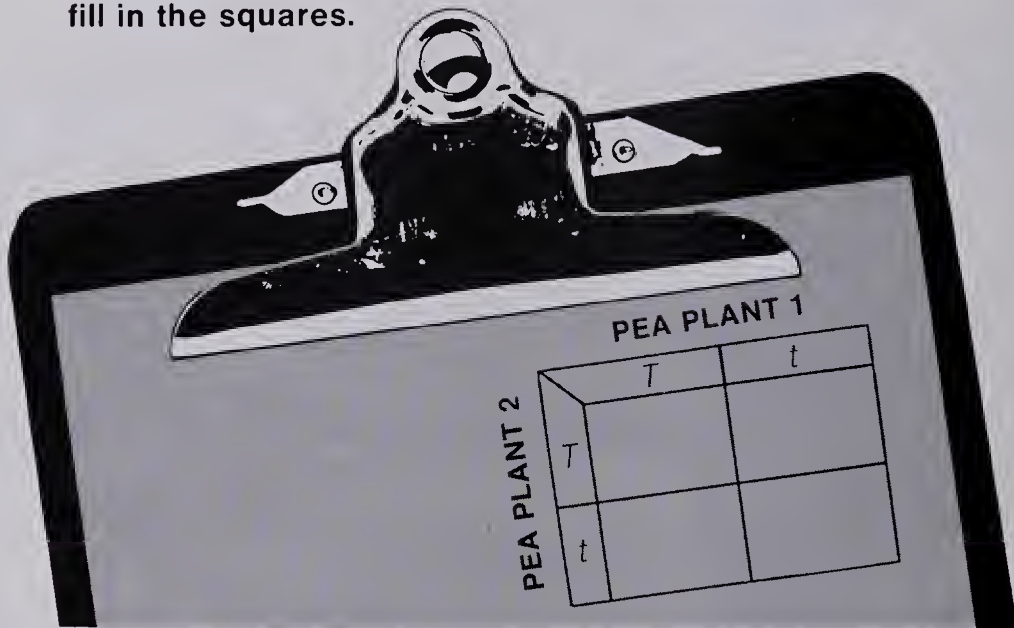


Figure 2–6

2–19. What are the chances of getting a pure-strain tall plant, *TT?* (Express your answer as the ratio *pure tall* to *not pure tall.)*

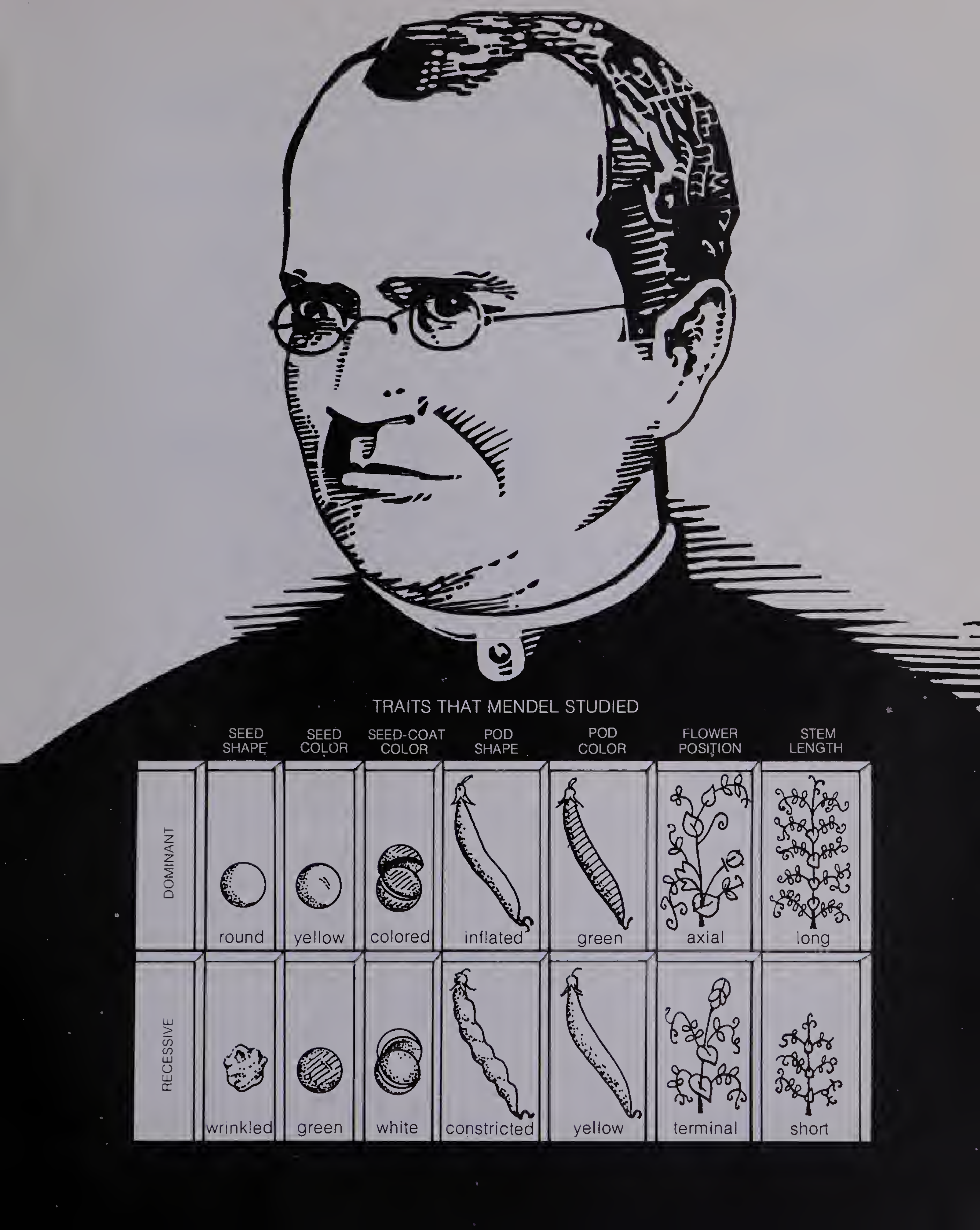
2–20. What are the chances of getting a pure-strain short plant, *tt?* (Express your answer as *pure short to not pure short.*)

2–21. What are the chances of getting a hybrid plant *Tt?* (Express your answer as *hybrid* to *not hybrid.*)

After Mendel studied one trait, like tallness, he studied another trait. In all, he studied seven traits of the garden pea. And all the traits followed the same rules.

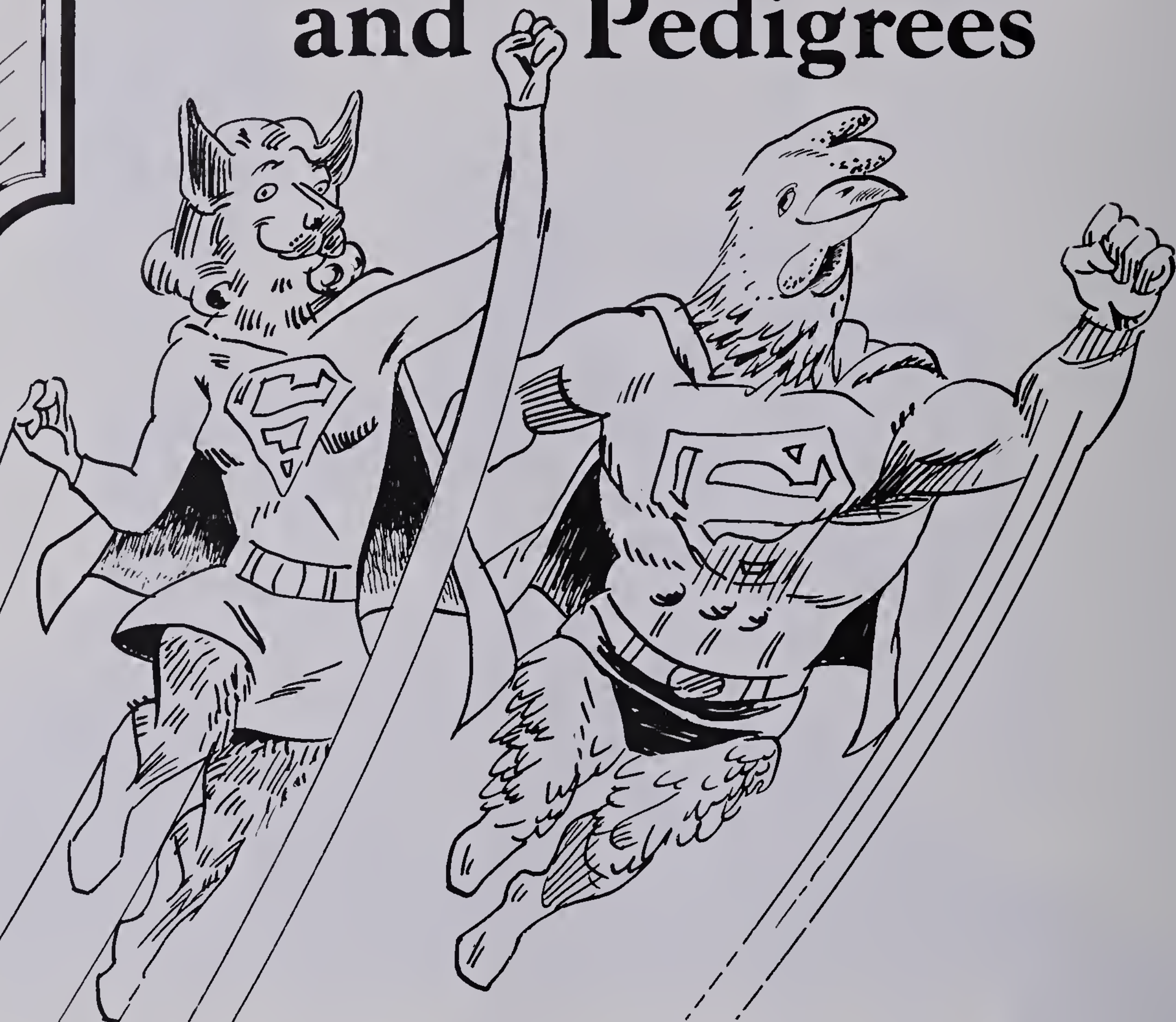
Many things have been discovered about heredity since Mendel's time. But the beginnings, the fundamental rules, can be credited to the man whose work went unnoticed for 35 years.

★ **2–22. Which of Mendel's contributions to the field of genetics do you think was most important?**


TRAITS THAT MENDEL STUDIED
SEED SHAPE
SEED COLOR
SEED-COAT COLOR
POD SHAPE
POD COLOR
FLOWER POSITION
STEM LENGTH
DOMINANT
round
yellow
colored
inflated
green
axial
long
RECESSIVE
wrinkled
green
white
constricted
yellow
terminal
short

Activity 3

Animal Breeding and Pedigrees



It's natural for us to want to improve ourselves and our surroundings.

Dairy farmers want their cows to give more milk. Horse breeders try to raise champion racers. Ranchers work to produce better beef cattle. Chicken farmers are always looking for better egg layers or meat producers. A dog or cat breeder tries to get finer pets with healthier coats and stronger bodies.

How do all these people get better animals? They use care in the breeding (raising) of animals.

When you hear about breeding better animals, you often hear about improving the bloodline. The idea that blood is the agent for heredity dates back to ancient times. Terms like "blue blood," "blood will tell," and "blood relative" came from this idea. Now it is known that blood plays no part in passing traits from generation to generation.

SELECTIVE BREEDING

The first step in developing better animals is to select animals that have the desired features. The dairy farmer who wants greater milk production chooses cows (females) that give a lot of milk. These cows are mated with a bull (male) that was born to a high milk-producing cow.

For the year 1900, the record for milk production by a Holstein cow was a little less than 8200 kilograms. Holstein cows were improved by care and breeding. Fifty years later the record was more than 20,000 kilograms of milk per year for a Holstein cow. (That's over 5000 gallons of milk!)

✔ 3–1. Look at the graph in Figure 3–1. During which ten-year period did milk production improve the most? The least? If you have trouble reading the graph, be sure to read *Resource Unit 2*.

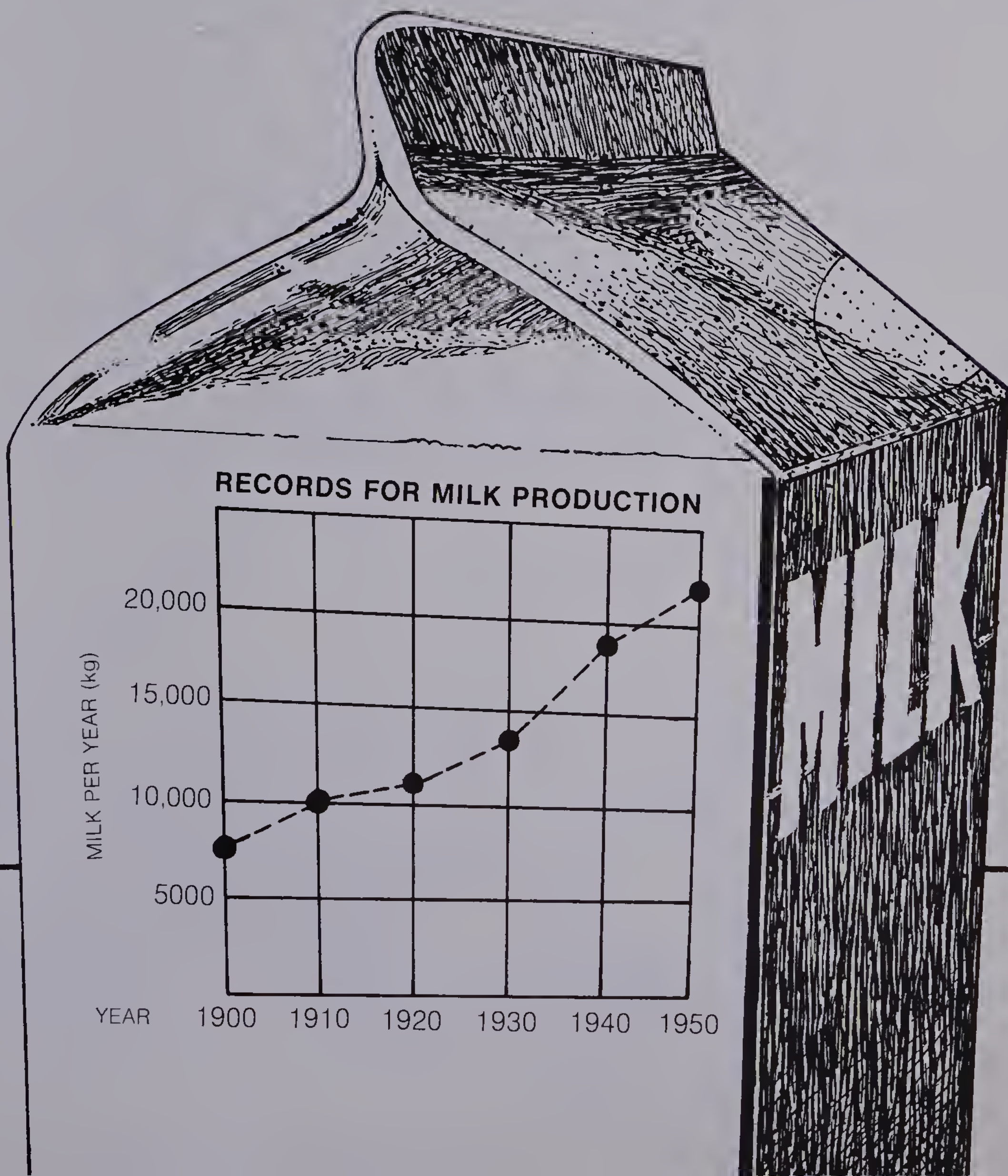


Figure 3–1

The richness of milk is important to dairy farmers. They can breed cows that produce large amounts of milk with a high butterfat content. They can also breed cows that produce large amounts of milk with a low butterfat content.

Rabbit raising for meat and fur has become popular. To be a successful breeder, a person must raise animals that have desired traits. Listed below are five desired traits.

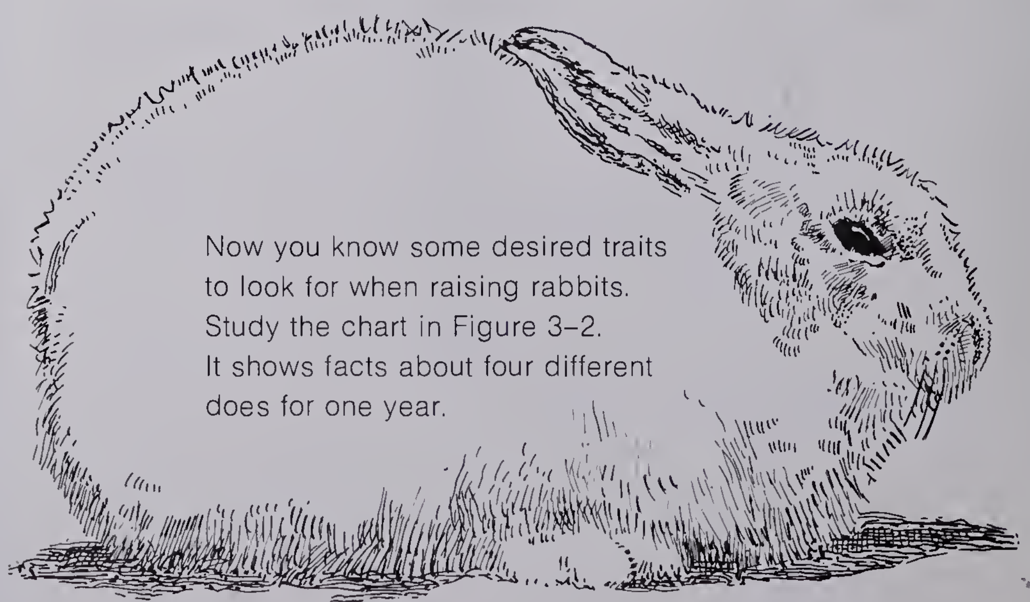
1. *Large Litters:* Some rabbits are more productive than others. A doe or female rabbit should produce a litter of seven to ten offspring.

2. *Milk production:* For three weeks, the young rabbits exist only on the doe's milk. They receive all their nourishment from this milk. The size of the offspring at three weeks is important. It indicates the size the rabbits will be at maturity. So, a doe must have a good supply of milk to "fatten up" her many young.

3. *Consistent reproduction:* A good breeding doe should bear five litters per year.

4. *Heavy meat type:* Eight weeks is the age of marketable rabbits to be used as fryers. At that age, a young rabbit should weigh about two kilograms (4.4 pounds). The entire litter should weigh about 15 kilograms (33 pounds).

5. *Disease resistance and long life:* Seven or eight (or more) of the offspring should survive the first eight weeks. And a good doe should bear twelve or more litters in her lifetime.



Now you know some desired traits to look for when raising rabbits. Study the chart in Figure 3–2. It shows facts about four different does for one year.

RABBIT BREEDING

DOE	LITTER	NO. BORN	3 WEEKS NO. ALIVE	3 WEEKS AVERAGE WEIGHT (kg)	8 WEEKS NO. ALIVE	8 WEEKS AVERAGE WEIGHT (kg)	8 WEEKS TOTAL WEIGHT PER LITTER (kg)
1	1	6	5	0.33	5	1.7	8.5
	2	5	5	0.34	5	1.8	9.0
	3	8	7	0.34	7	1.8	12.6
	4	6	5	0.43	5	2.2	11.0
	5	6	4	0.44	4	2.3	9.2
Averages for the Year			5.2	0.38	5.2	1.96	10.06
2	1	9	7	0.30	7	1.8	12.6
	2	8	7	0.31	6	1.9	11.4
	3	8	8	0.27	6	1.7	10.2
	4	6	5	0.30	5	1.8	9.0
Averages for the Year			6.75	0.30	6	1.80	10.80
3	1	10	8	0.32	8	1.9	15.2
	2	9	8	0.37	8	2.0	16.0
	3	7	7	0.38	7	2.2	15.4
	4	7	7	0.42	7	2.1	14.7
	5	12	8	0.34	8	1.9	15.2
Averages for the Year			7.6	0.37	7.6	2.02	15.30
4	1	9	8	0.26	8	1.5	12.0
	2	8	8	0.25	8	1.2	9.6
	3	10	9	0.23	8	1.1	8.8
	4	8	7	0.27	7	1.6	11.2
	5	10	9	0.23	9	1.0	9.0
Averages for the Year			8.2	0.25	8.0	1.28	10.12

Figure 3–2

✔ 3–2. Which doe rates the highest in Trait 4? What is the total amount of meat this doe produced in a year?

✔ 3–3. Which doe rates the highest in Traits 1 and 5?

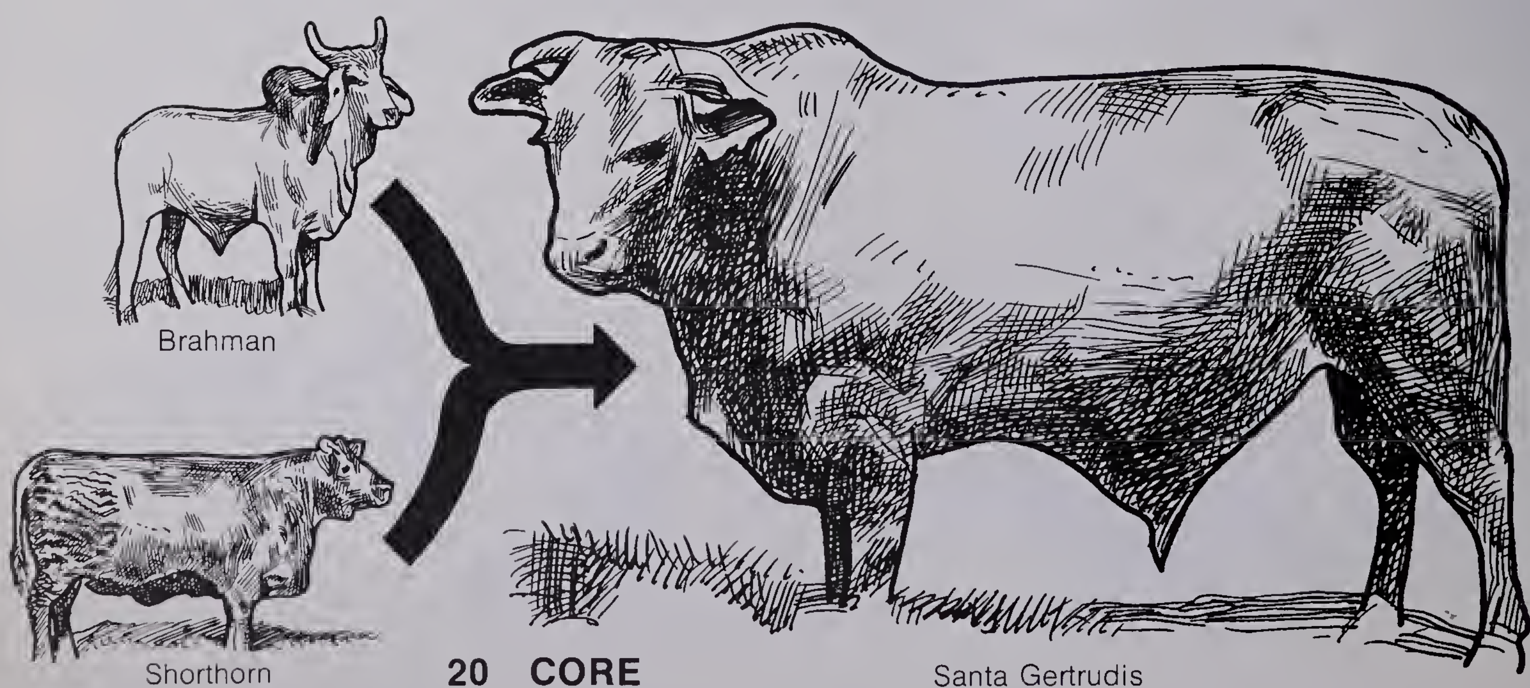
Animal breeders study facts like those in Figure 3–2. They select the animal that rates the highest in the desired trait. They choose the best offspring of that animal for future breeding.

CROSSBREEDING

It may be desirable to introduce special traits to a particular breed. To do this, two different breeds, each with a desirable trait, are mated. For example, a hardy, disease-resistant strain of turkey is crossed with a strain that has an extremely broad breast. After many such crossings, healthy meaty birds are produced. These are the turkeys that are sold in supermarkets.

In the early 1900s, a disease called *Texas Fever* killed many cattle in the United States. The disease was spread by ticks. The *Brahman* cattle from India were immune to Texas fever. But Brahman cattle produced a poor grade of beef.

Cattle breeders selected their best beef-producing cattle called *Shorthorn* cattle. They crossed the Shorthorn with the Brahman cattle. The offspring from each crossing were studied. Those that were resistant to Texas fever and were good beef producers were selected for future breeding. They were called *Santa Gertrudis* cattle.

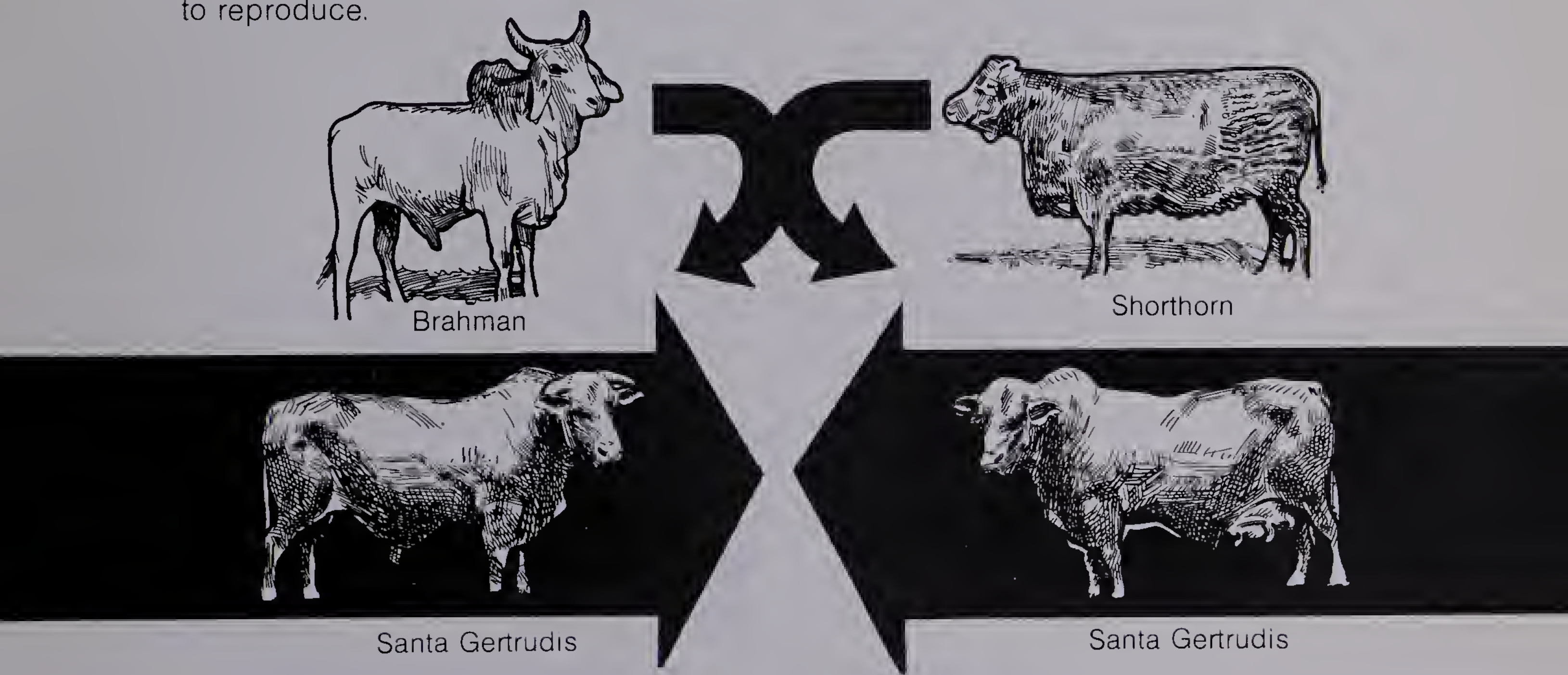


★ 3–4. How is crossbreeding different from selective breeding?

INBREEDING

Probably the most common way of continuing a desired breed is by inbreeding. This is done by mating two animals from the same set of offspring. The animals selected both have the desired traits. It is very likely that their offspring will have the desired traits.

But there is a danger in inbreeding. Animals from the same set of offspring often have the same *undesirable* traits. When the animals are mated, there is a chance that their offspring will inherit these traits. If this happens, the offspring are not allowed to reproduce.



KEEPING TRACK

Animal breeders don't leave the matings of their animals to pure chance. They use selective breeding, crossbreeding, and inbreeding very carefully. And they keep a record of the results. A record of heredity is called a *pedigree* or family tree.

A pedigree of a cross between a Shorthorn cow and a Brahman bull is shown in Figure 3–3. The two traits studied are meatiness and resistance to disease.

In pedigrees, squares represent males and circles represent females. Unshaded symbols represent organisms that do not show the traits studied. A horizontal line between two symbols shows a mating. A double horizontal line between two symbols shows inbreeding. Vertical lines from a mating lead to the offspring.

In Figure 3–3, vertical lines within a symbol represent meatiness, as in Shorthorn cattle; horizontal lines represent resistance to disease, as in Brahman cattle. Both vertical and horizontal lines indicate that the offspring shows both traits. Generation numbers are at the left. Generation 1 is made up of the first set of offspring and Generation 2, the second set.

Suppose that selective breeding has produced a good Shorthorn female, 1, and a good Brahman male, 2. They are mated, and have offspring 3, 4, 5, and 6.

3–5. Study offspring 3, 4, 5, and 6. Which show both the desired traits?

3–6. Would offspring 3 or 6 be allowed to reproduce? Why or why not?

The cattle numbered 4 and 5 show the desired traits. They are mated. Their offpsring are 7, 8, 9, 10, and 11. Notice the double line between 4 and 5. The mating is an example of inbreeding.

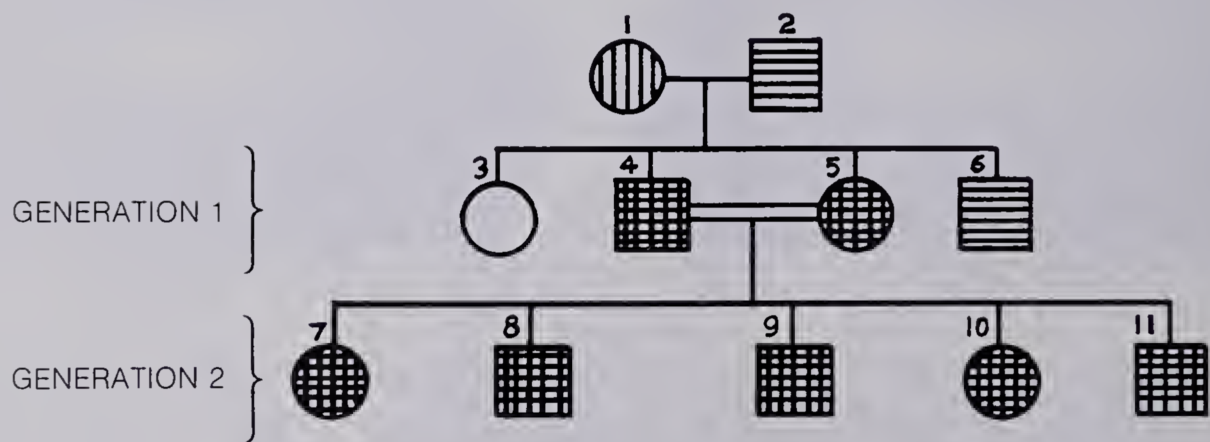


Figure 3–3

3–7. Look at the offspring from the mating of 4 and 5. Do the offspring have desirable or undesirable traits?

Offspring 7, 8, 9, 10, and 11 are watched closely to see if an undesirable trait appears. If it does, the cow or bull having the trait will not be allowed to reproduce.

HUMAN PEDIGREES

Everyone has a pedigree or family tree. Your pedigree shows every relative (living or not) that you can trace. Your mother and father are in your pedigree. So are any sisters or brothers that you have. And your mother's and father's parents are in your pedigree. (They are your grandmothers and grandfathers.) You may even be able to show your great grandparents' generation.

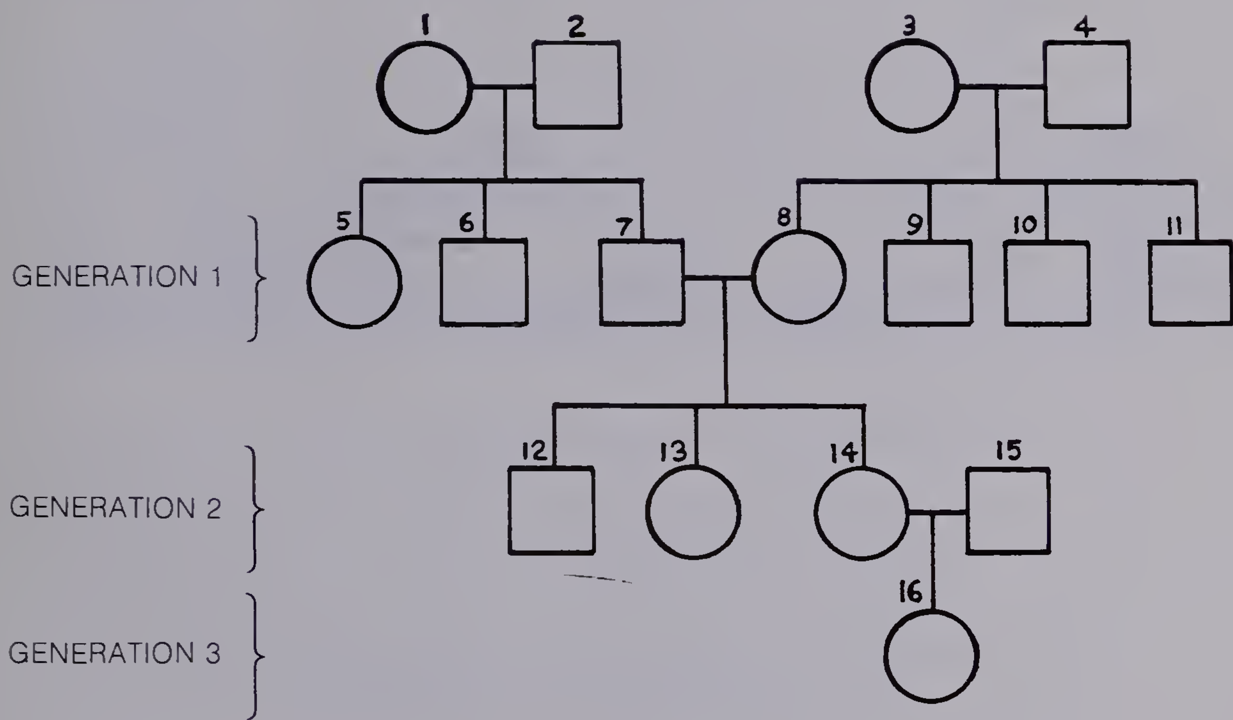


Figure 3–4

Suppose that the pedigree in Figure 3–4 is your family's chart. Your grandparents are 1, 2, 3, and 4; your father and mother are 7 and 8. You are either 12 or 13. If you are 12, your sister is 13. If you are 13, your brother is 12. Your aunts and uncles are 5, 6, 9, 10, and 11. Notice that 14 is your sister who is married to 15. They have a daughter, 16, who is your niece.

★ 3–8. On a separate sheet of paper, draw a family tree for the members of your family.

Go back as far as you can. Make it as complete as possible. Be sure to include all your relatives, living or not. You may want

to sketch the chart first to see how much space is needed. You'll use the completed family tree for an investigation.

IMPORTANT: If your own family tree is too difficult to draw, make up one.

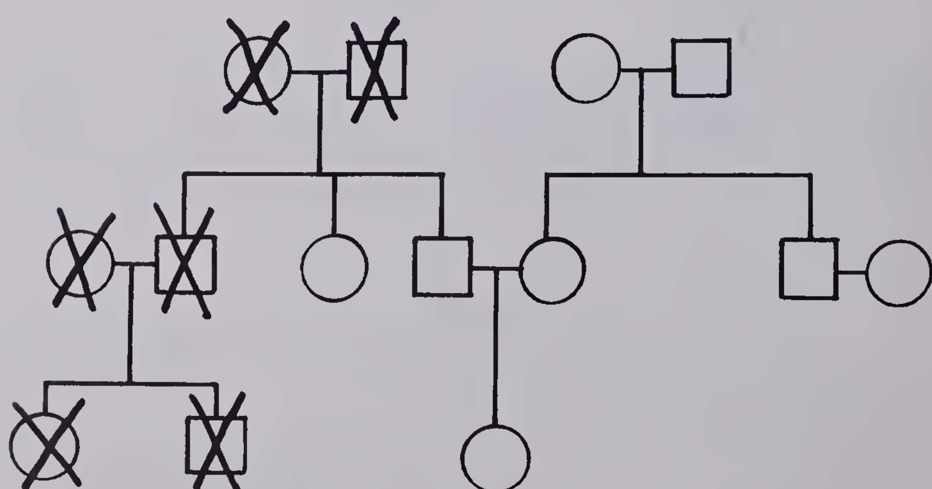
FOLLOWING A TRAIT

There is a trait that is easily tested. It is the ability to taste a harmless chemical called *PTC*. The full name of the chemical is *phenylthiocarbamide* (fen-al-thigh-oh-CAR-ba-mide). To a majority of people in North America, this chemical tastes bitter. To the rest of the people, it has no taste. The ability to taste or not taste PTC is a trait that is inherited. In this investigation, you are going to find out which members of your family have this trait. You will need the following materials:

2 or 3 strips of PTC paper
family tree, prepared for Question 3–8

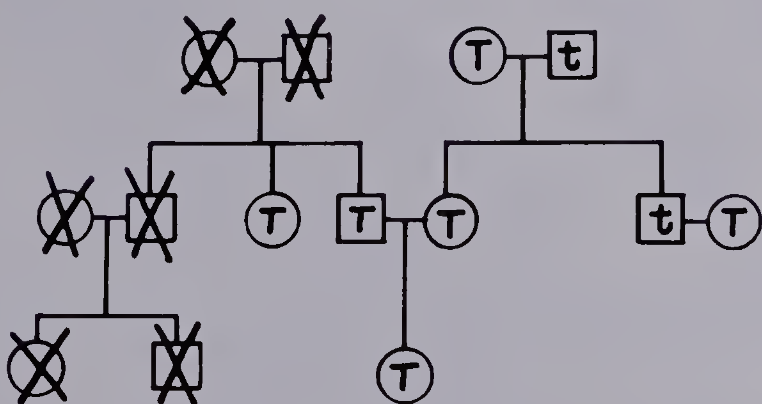
If you were not able to draw your own family tree, use a friend's data for this investigation.

A. Look at your family tree. Which relatives will you be able to test? Count them. You might want to draw *X's* for the relatives you can't test.



B. Cut each PTC strip into four equal pieces. You will need a piece for each person to be tested. Put the PTC pieces into an envelope or a clean, folded paper. Take the strips home. Also take home your family tree.

C. Give each family member (yourself included) one PTC piece to put on the tongue. If the person tastes the PTC piece, that person is a "taster". Write *T* in the proper symbol on the family tree. If the person cannot taste the PTC piece, the person is a "nontaster". Write *t* in the proper symbol.



✔ 3–9. Are you a taster or a nontaster?

✔ 3–10. How many members of your family (or your friend's family) are tasters?

✔ 3–11. How many are nontasters?

Activity 4

Plant Breeding

Your life and every other person's life depends on green plants. They are the source of all human food. Either you eat green plants or you eat the animals that feed on the plants. The world population is crying for more and more food. If we can increase the amount of food that plants produce, we can feed more people. Is it possible to grow more plants? Better plants?

There is evidence that grain was planted and harvested about 10,000 years ago. The results of the early efforts were not as exciting as the results today. For instance, at least 7000 years ago the American Indians grew corn. Each ear of corn had about forty-eight kernels. Today, an ear may have up to 1000 kernels. In some of the oldest Indian campsites, ears of corn were found. These ears were only five centimetres long. In more recent campsites, the ears found were ten centimetres long. Today it is common for an ear of corn to be twenty centimetres long!

✔ 4–1. What are the reasons for this increase in the length of an ear of corn?

5000 B.C.

48 kernels 5 centimetres long

1975

1000 kernels 20 centimetres long

Not much is known about how people improved their crops thousands of years ago. But careful selection of seeds could account for some improvement. In the twentieth century, the greatest gains have been in the creation of *hybrids*. A hybrid is an organism whose parents do not have the same genes for a certain trait.

Today agricultural researchers work full time producing new hybrid plants. In the United States, 98% of all corn planted is hybrid corn. The yield is good; the corn is healthy. In fact, the average harvest produces three times as much corn as in pre-hybrid days. How is a hybrid plant produced? To answer this question, you must understand the structure of a flower.

A cutaway view of a flower is shown in Figure 4–1. Each flower has a female reproductive organ (part) called the *pistil*. At the base of the pistil there is an *ovary*. Seeds are produced in the ovary. The top of the pistil has a sticky surface.

Each flower has male parts called *stamens*. (See Figure 4–1.) At the top of each stamen is the *anther*. Tiny grains called *pollen* are produced on the anther. The stamen controls the production of pollen.

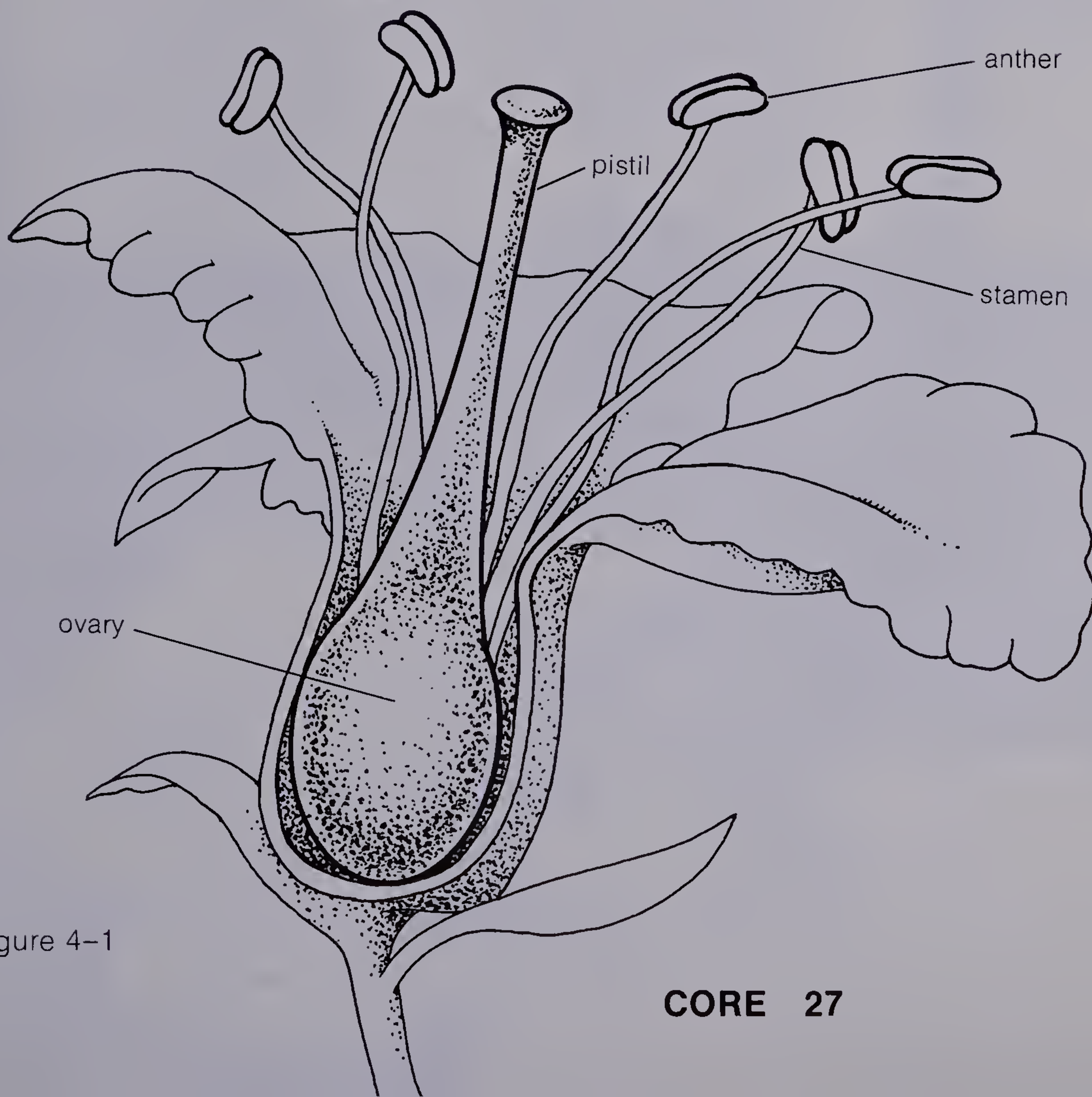
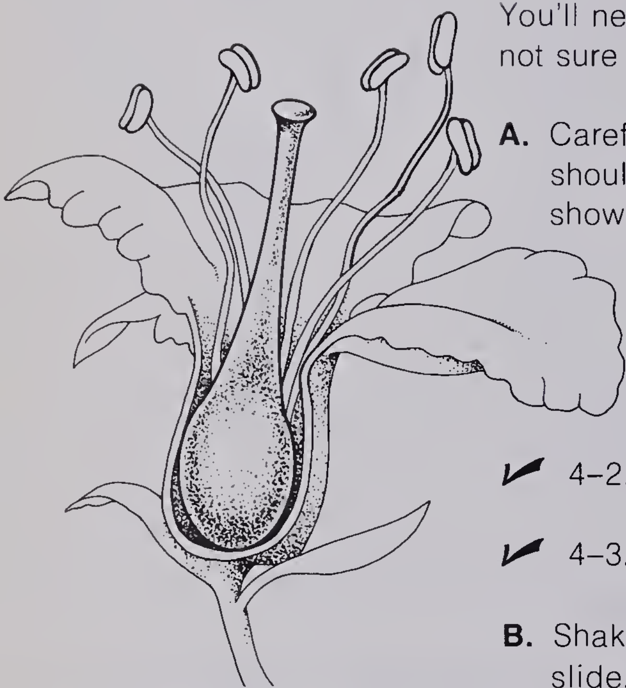


Figure 4–1

Now examine a flower and locate the pistil, ovary, stamen, and pollen. You will need the following materials:

flower
microscope slide
microscope

You'll need a microscope to examine pollen grains. If you are not sure how to use a microscope, read *Resource Unit 3*.



A. Carefully remove some petals. The inner parts of the flower should be visible. Match the parts of the flower with those shown in Figure 4–1.

✔ 4–2. In your notebook, sketch the flower and label the parts.

✔ 4–3. How many stamens are there? How many pistils?

B. Shake some pollen from your flower onto a microscope slide. Put the slide under the microscope. Observe the grains.

✔ 4–4. In your notebook, sketch and label a pollen grain.

Pollen grains vary from one kind of plant to another (Figure 4–2). Some are irregular and rough. Some are round and smooth. Some have sharp spikes.

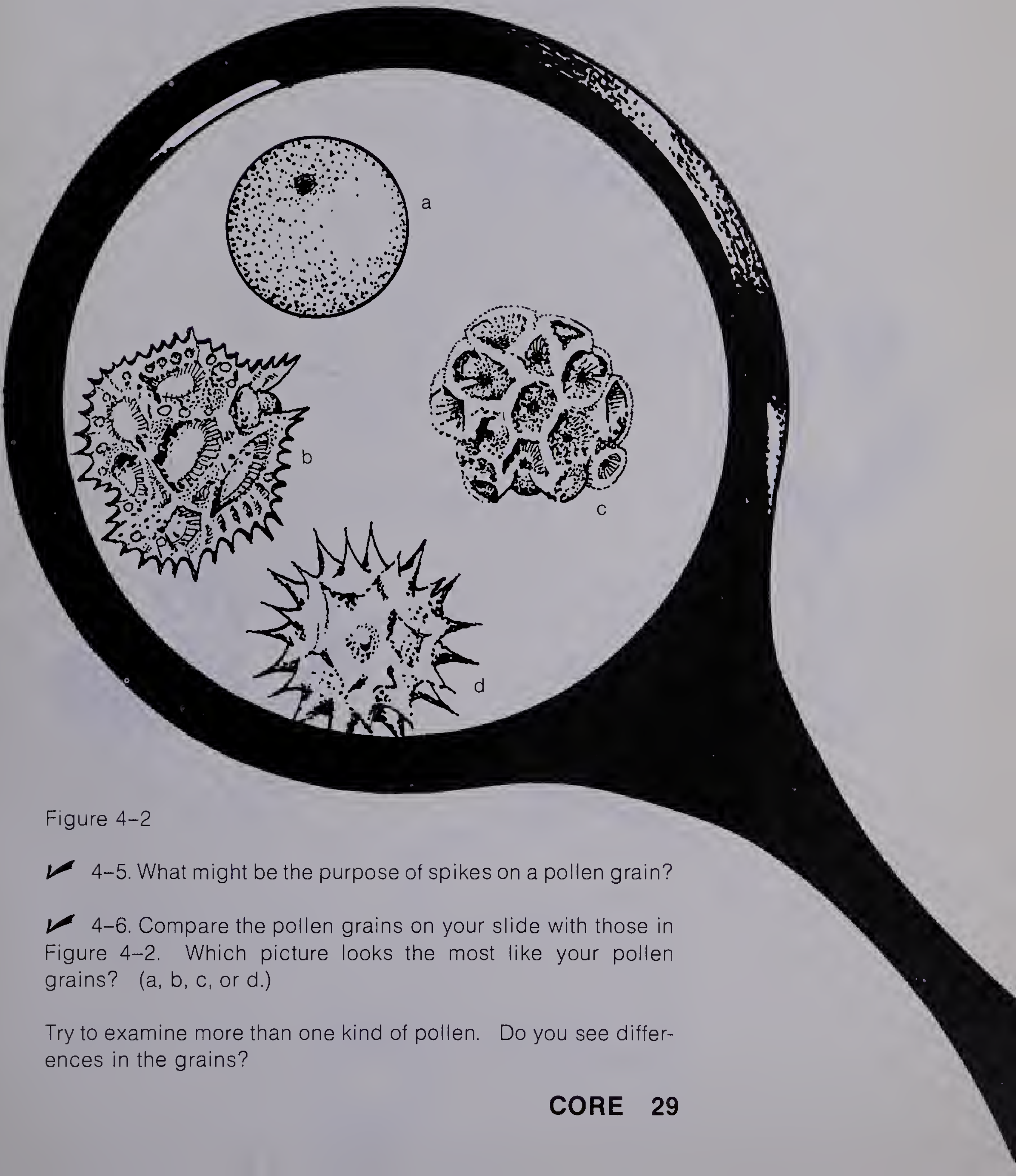


Figure 4–2

✔ 4–5. What might be the purpose of spikes on a pollen grain?

✔ 4–6. Compare the pollen grains on your slide with those in Figure 4–2. Which picture looks the most like your pollen grains? (a, b, c, or d.)

Try to examine more than one kind of pollen. Do you see differences in the grains?

POLLINATION

The pollen from an anther is blown, falls, or is carried by an insect. Some of it may land on a pistil (Figure 4–3). This transfer of pollen is called *pollination*.

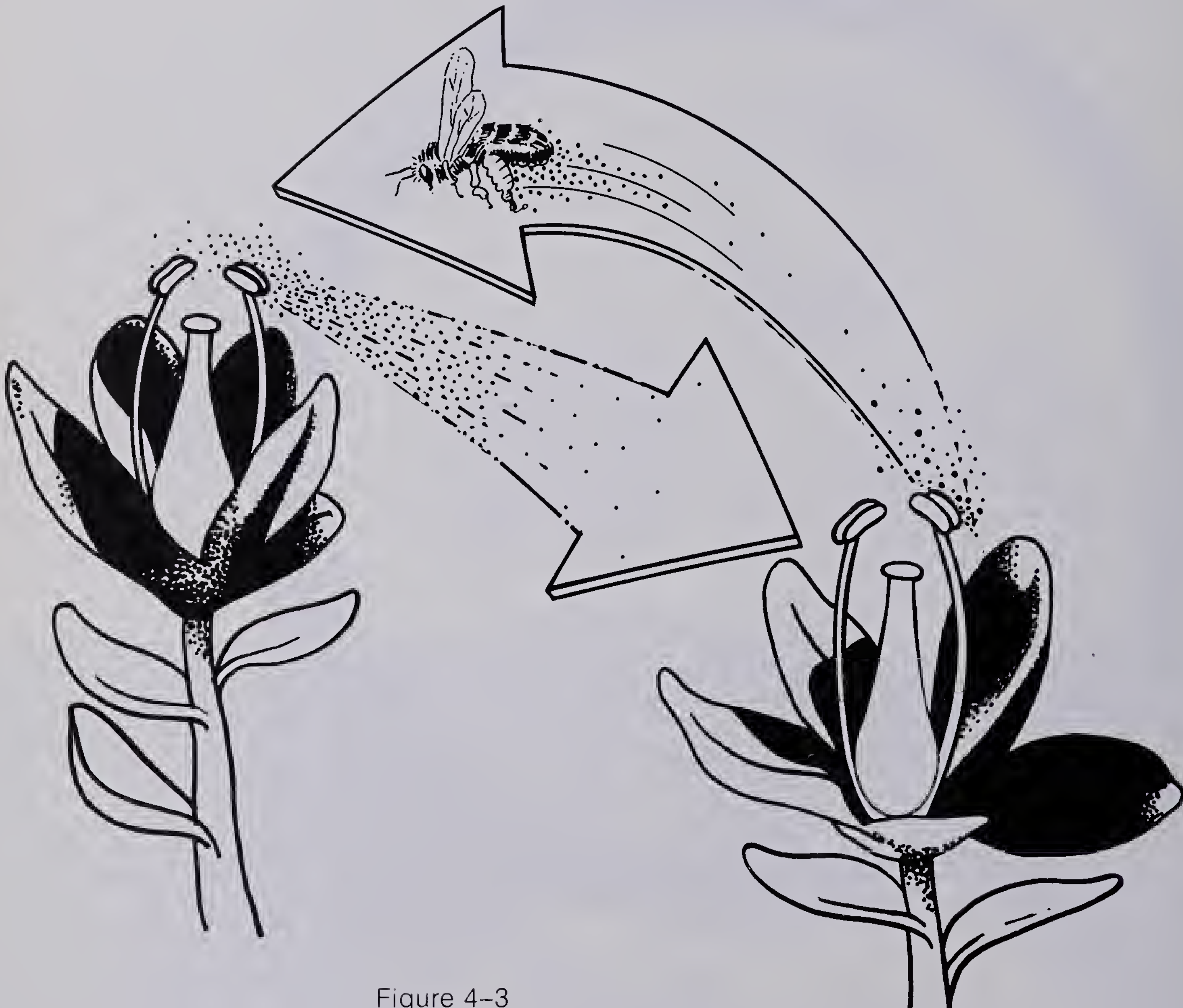


Figure 4–3

The pollen of a flower may stick to the pistil of the same flower. This is called *self-pollination*. If the pollen sticks to the pistil of a different flower, it is called *cross-pollination, crossbreeding,* or *crossing*.

★ 4–7. Why do you think there is usually more than one stamen but only one pistil?

Many times it's desirable to improve a seed. Then two particular plants are crossed. This "controlled" crossing is called *artificial pollination.* This is how it is done:

First the stamens are removed from a flower (Figure 4–4).

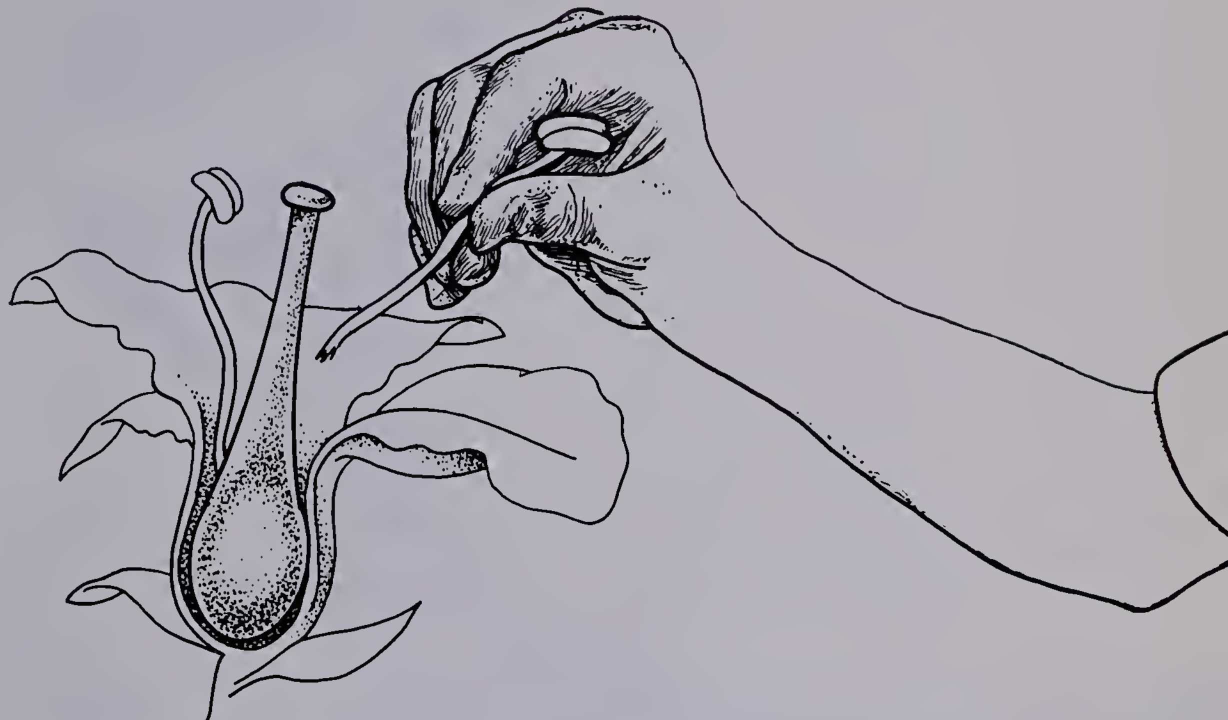


Figure 4–4

4–8. Should the removal of the stamen be done *before* or *after* any pollen is shed?

Then pollen from the desired plant is dusted onto the top of the pistil (Figure 4–5). The flower must get only the pollen dusted on it.

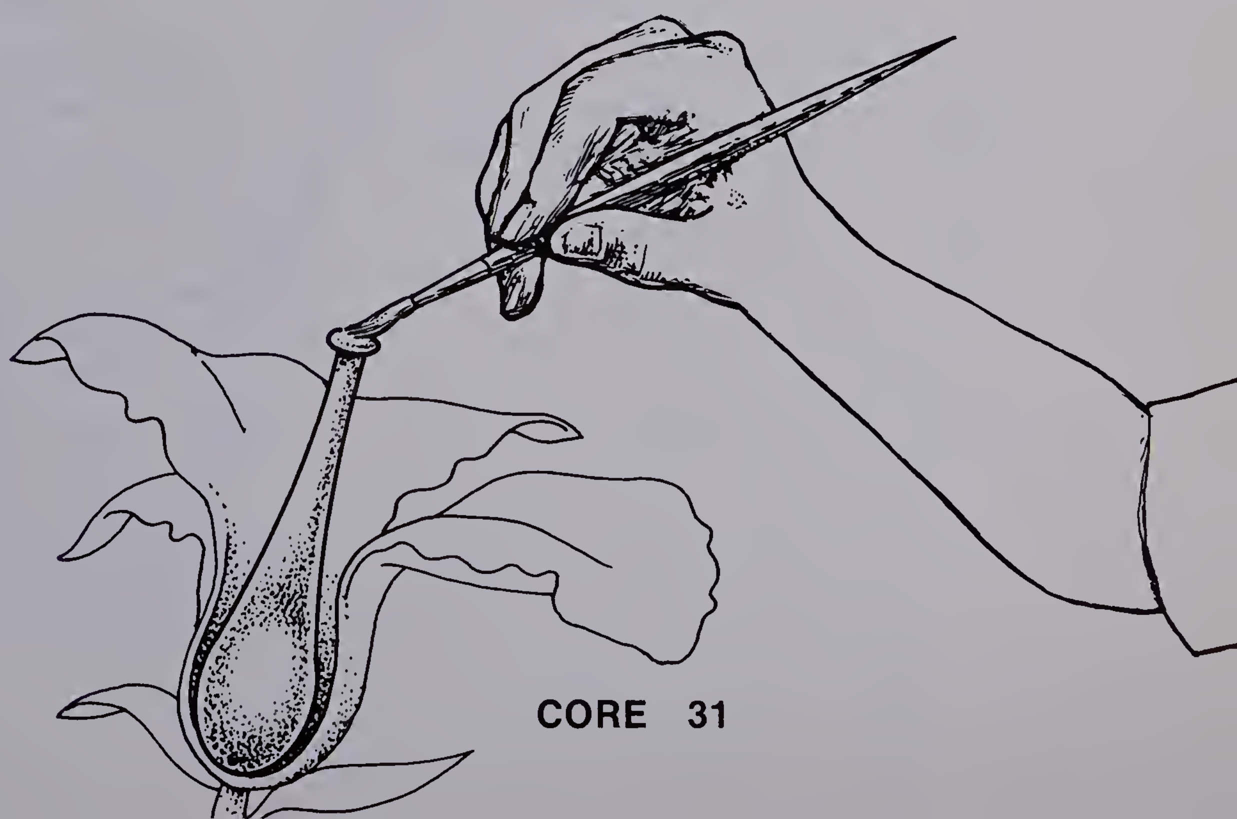


Figure 4–5

The flower is covered with a bag until fertilization is complete. A cutaway view of the bag is shown in Figure 4–6.

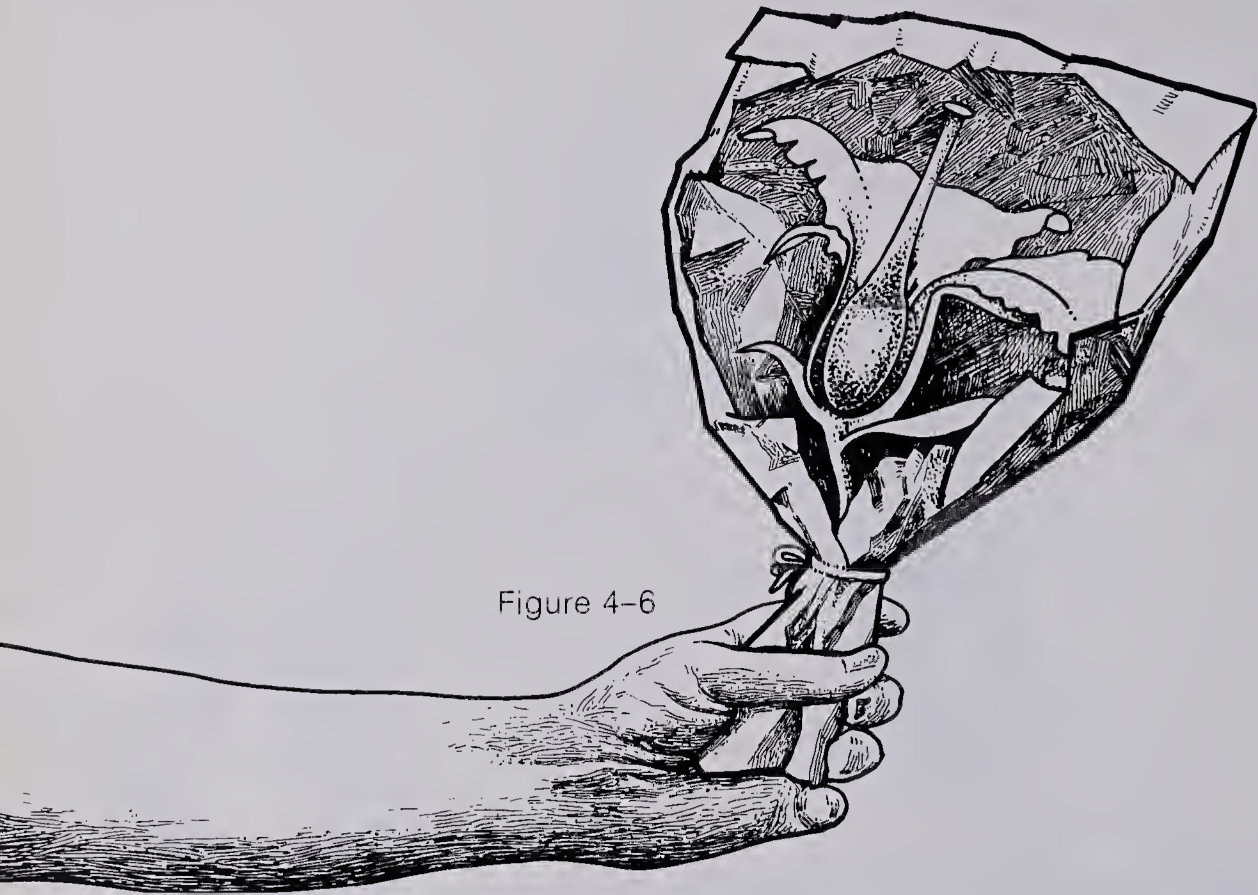


Figure 4–6

★ **4–9. Match the letter of each type of pollination with two or more processes that describe it.**

TYPE OF POLLINATION

a. Self-pollination
b. Artificial pollination
c. Cross-pollination

PROCESS

1. **The pollen that sticks to the pistil comes from a stamen.**
2. **The pollen that sticks to the pistil comes from another pistil.**
3. **The pollen that sticks to the pistil comes from a stamen of the same flower.**
4. **The pollen that sticks to the pistil comes from a stamen of a different flower.**
5. **The pollen that sticks to the pistil is placed on the pistil by a person.**

FERTILIZATION

For fertilization to occur, a pollen grain must get inside the ovary to an *ovule* (OV-yule) or egg. There may be one or many ovules, depending on the type of plant.

When pollen falls on the pistil of a living flower, the cells of the pistil produce a fluid. This fluid stimulates a pollen grain to grow a pollen tube. The slender, thin-walled tube grows down the pistil toward the ovary. Each pollen grain has two *nuclei* (NEW-klee-eye).

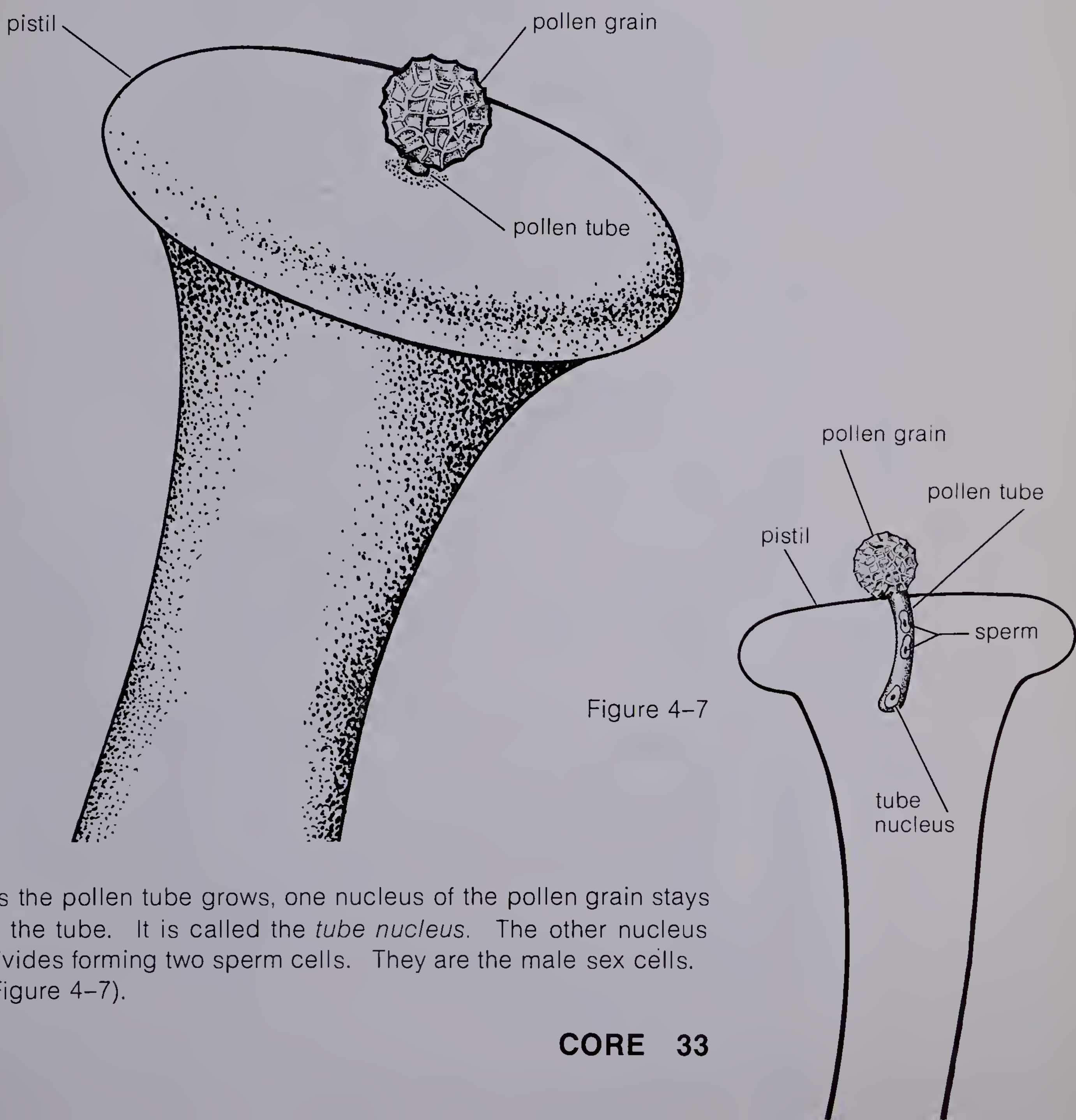


Figure 4–7

As the pollen tube grows, one nucleus of the pollen grain stays in the tube. It is called the *tube nucleus*. The other nucleus divides forming two sperm cells. They are the male sex cells. (Figure 4–7).

When the pollen tube reaches the ovary, it goes through a small channel into the ovule. Then the end of the pollen tube breaks. The two sperm are released. The nucleus of one of the sperm joins with the nucleus of the *egg*, the female sex cell. The joined nuclei develop into a seed. The nucleus of the other sperm joins with two nuclei of the other cells in the ovule. These joined cells develop into the food part of the seed. (Figure 4–8.) Fertilization is complete when the nuclei are joined.

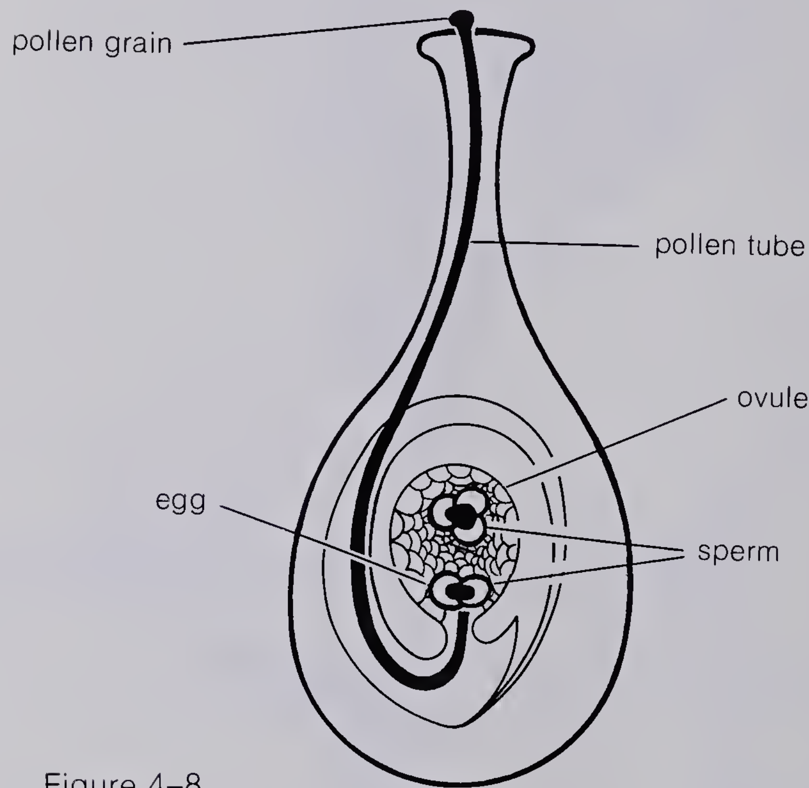


Figure 4–8

The sperm and the egg each have units of heredity called *genes*. The genes control the traits of the plant. When the sperm and egg are joined together in fertilization, the new seed gets genes from both parents. Genes are "links" between parents and offspring.

★ 4–10. If an ovary contains eight egg cells, how many seeds can form?

It is possible for grains of pollen from several plants to fertilize the ovules of one plant. Then the seeds of the plant have different male parents. This can happen only when all the plants are of the same variety (buttercups, for example).

4–11. Suppose the seeds of a plant have different male parents. What effect would this have on the genes in the seeds?

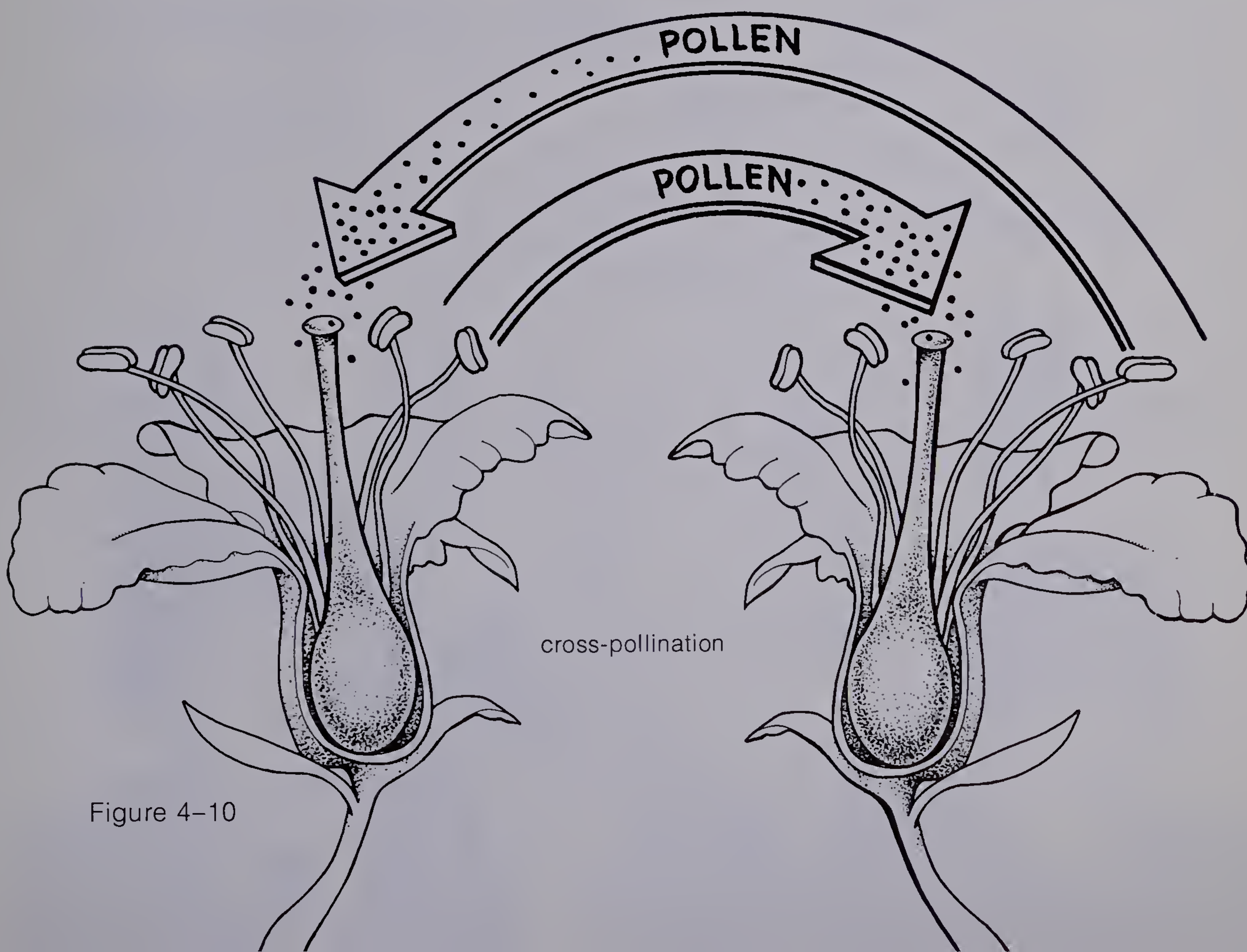
CREATING THE STRAIN

self-pollination

Figure 4–9

Suppose you want to develop a strain or type of plant that has certain traits. For example, a strain of wheat may have a high yield and be resistant to disease. First, you would find a pure strain plant for each of these traits. To be sure that the plants were pure, you would let them self-pollinate for a number of generations (Figure 4–9). After each pollination, you would plant the fertilized seeds and study the new plants. If the strain was pure, the desired trait would show up in every offspring for several generations.

Then the pure plants would be crossed (Figure 4–10). The fertilized seeds from the crossing would be planted. From some of these seeds there'd grow wheat that has a high yield and is disease-resistant. By crossbreeding other strains with this one, more traits can be added. A strain can be developed that has a high yield, is disease-resistant, can withstand a severe winter, and can withstand dry weather.



cross-pollination

Figure 4–10

Rice is one of the world's most important grains. It is produced as a hybrid. The International Rice Research Institute has developed a new strain of rice. The plant is short and stiff. It is not beaten down by wind and rain. It is easy to harvest. It is resistant to pests and disease. It has high food value. More than four times as much rice per acre is being produced from this new strain.

MAINTAINING A STRAIN

Once a desired plant strain has been developed, it can be maintained. This is normally done by taking cuttings from the hybrid plant or by planting bulbs of the hybrid.

★ 4–12. Is self-pollination the most common way to maintain a hybrid strain?

When maintaining a strain there is no mixing of genes as there is when developing hybrids. The same genes of the parent plant are carried to the offspring, generation after generation. These breeding methods are used especially with flowers. Consider rose breeding. A desired strain of roses is established by crossbreeding. Then cuttings from the hybrid plant are grafted (joined) with a healthy plant from a less desirable strain (Figure 4–11). The offspring are developed by cutting, not pollination. And the resultant roses look exactly like the parent rose.

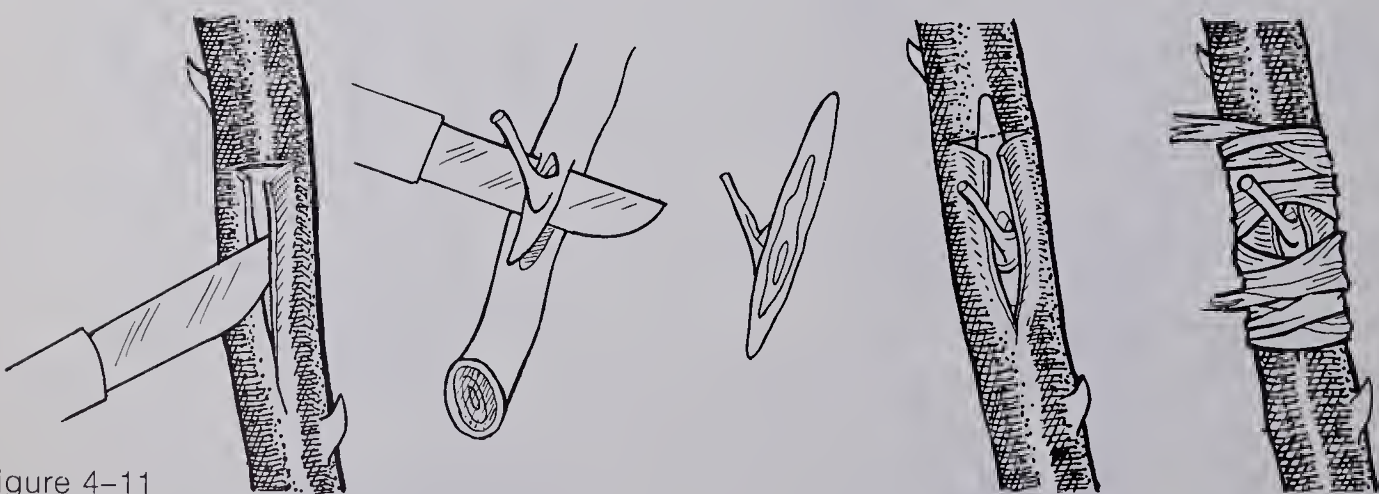


Figure 4–11

✔ 4–13. How do the genes in the parent rosebush compare with those in the grafted rosebush?

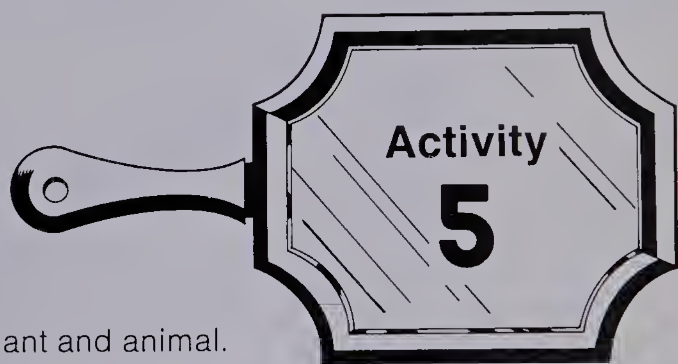
This kind of breeding is also used with the begonia, a flowering house plant. The modern varieties were bred from wild begonias. A tiny South American begonia was crossed with other wild varieties. And an amazing assortment of flowers has been produced. The flowers look like roses, camellias, and carnations, in brilliant colors.

Some flowers have a diameter that is six times greater than the little wild flower from which they came. Once a beautiful hybrid is developed, it can be duplicated endlessly.

Careful breeding of plants has made them bigger, more beautiful, more fruitful, and more resistant to disease. In fact, plant breeding has improved nature. It has been said that if nature had not been improved, only 1 person out of 1000 would be on Earth today.

✔ 4–14. If nature was not improved, would Earth be better or worse than it is today? Give reasons for your answer.

Changing the Signals



Genes are tiny units that are in every cell of a plant and animal. A gene has two roles to play. One role is to duplicate (copy) itself each time the cell divides. As a result, the new cells

should have exactly the same genes as the original cell. The other role is to control the traits (characteristics) of plants and animals.

Genes control your physical traits and some of your emotional traits. They control the color of your eyes, the size of your feet, the natural color of your hair, and thousands of other traits. It is estimated that there are over 10,000 different genes in a single human cell!

Genes seem to be strung together in chainlike forms called *chromosomes*. Some chromosomes are pictured in Figure 5--1. Notice the light and dark bands. They are genetic units made up of one or more genes.

Figure 5–1

Genes are very stable. They usually reproduce exact copies of themselves (Figure 5–2).

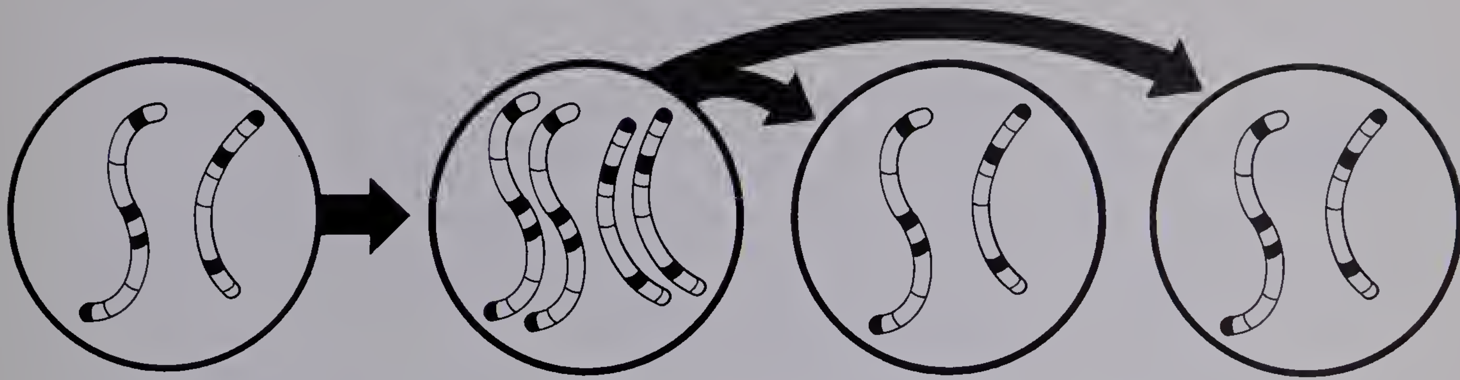


Figure 5–2

But every once in a while the copy is not exact; it is changed. This change is called a *mutation*. A mutation can occur in many ways. The order of genetic units in a chromosome may change (Figure 5–3); a genetic unit may break away from the chromosome; there may be a change in the gene itself.

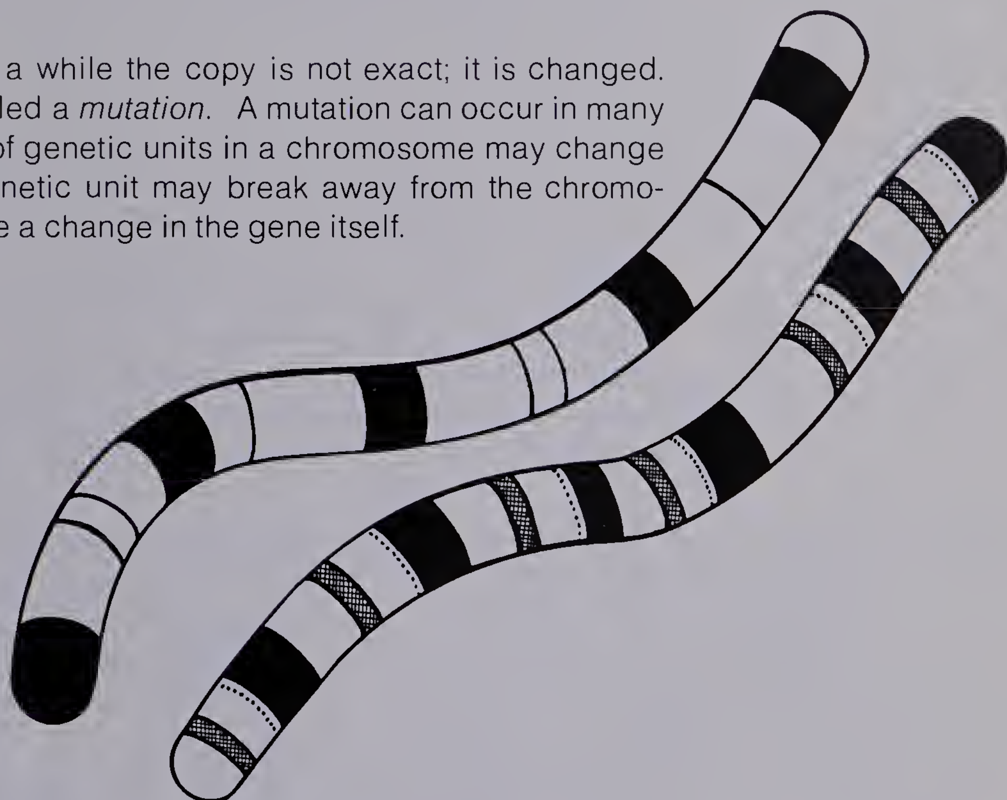


Figure 5–3

Most scientists believe that genes are chemical substances. They believe that a change in a gene is a change in the chemical substance.

★ 5–1. What can happen when part of the chemical substance of a gene is changed?

Scientists cannot yet determine when or where mutations occur. But there are ways to make mutations occur faster.

Higher temperatures and certain chemicals can increase the mutation rate of certain genes in the reproductive cells. Drugs

like thalidomide can cause mutations that deform a developing fetus. High energy radiation like X rays and the rays from an atomic explosion can cause mutations.

✓ 5–2. Some chemicals are believed to cause damage to the chromosomes. What effect might this have on future offspring?

★ **5–3. There is an easy way to remember three things that can increase the mutation rate of certain genes in the reproductive cells. Just remember the letters c, *h, r.* What does each letter stand for?**

A mutation may affect a cell very slightly. In fact, many mutations go undetected. However, a mutation may cause the death of a cell. Most mutations cause results that are between these two extremes.

The effects of a mutation will be studied in this activity. You won't cause a mutation to occur. Instead, you'll study an organism that shows the effects of a mutation. You'll compare the mutated traits with the original trait.

A likely candidate to study is the garden pea. Sometimes a single pea plant will have two forms of peas: round and wrinkled (Figure 5–4). As long as both forms are from the same organism, one may be considered a mutation of the other. It is important to note that wrinkling and roundness are two distinct traits. (Wrinkling is not caused by a lack of water in round peas.)

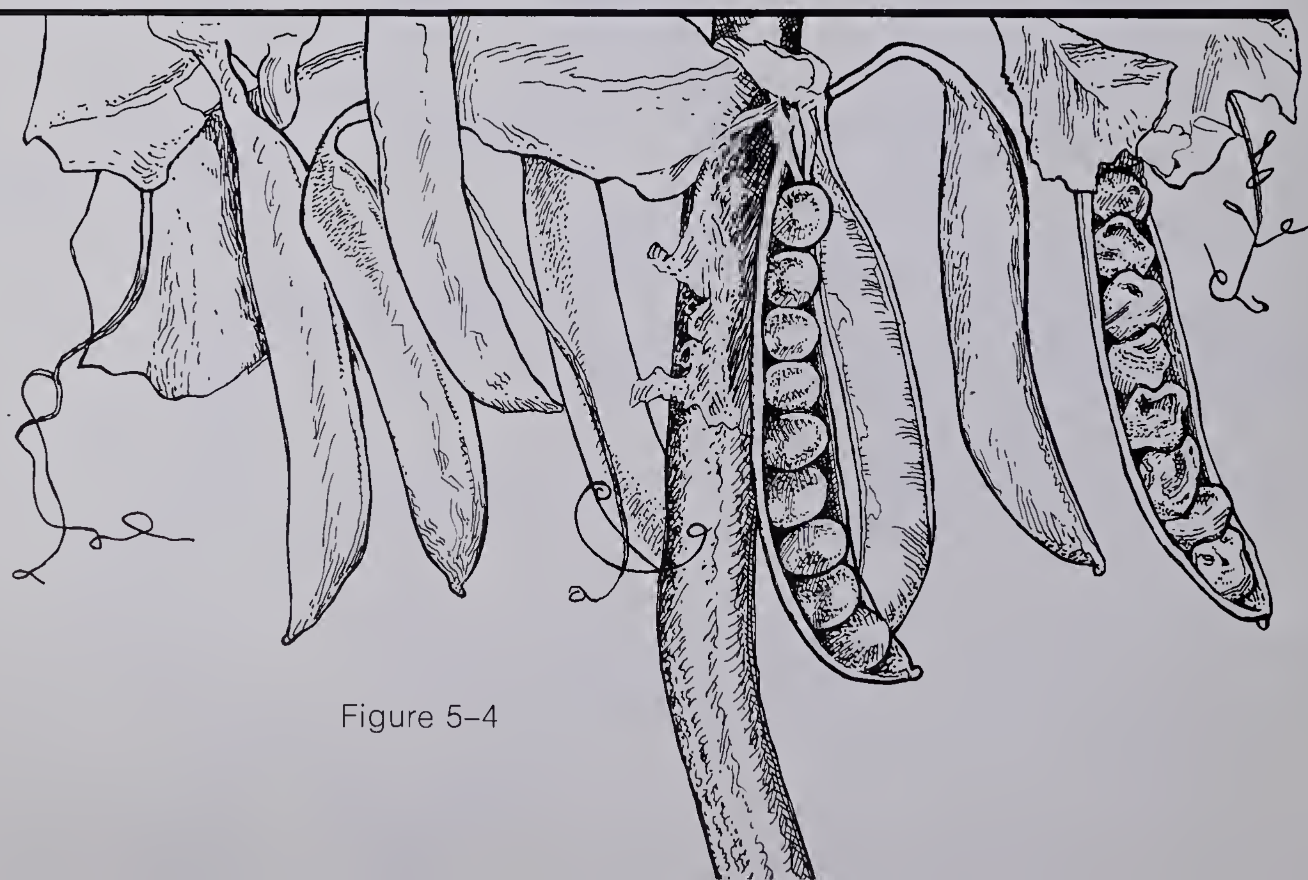


Figure 5–4

An important function of any green plant is food making. The pea makes large starch molecules from smaller, simpler sugar molecules (Figure 5–5). This process is controlled by a single gene.

Is there a difference in the starch-making ability of round and wrinkled peas? One way to find out is to extract (remove) and test the starch-forming substance from each type of pea. That's what you'll do in the following investigation. You'll need these materials:

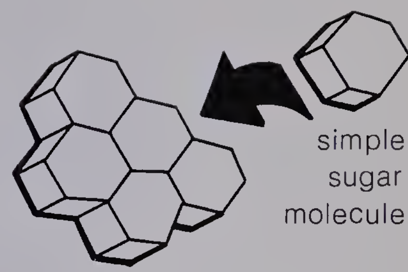


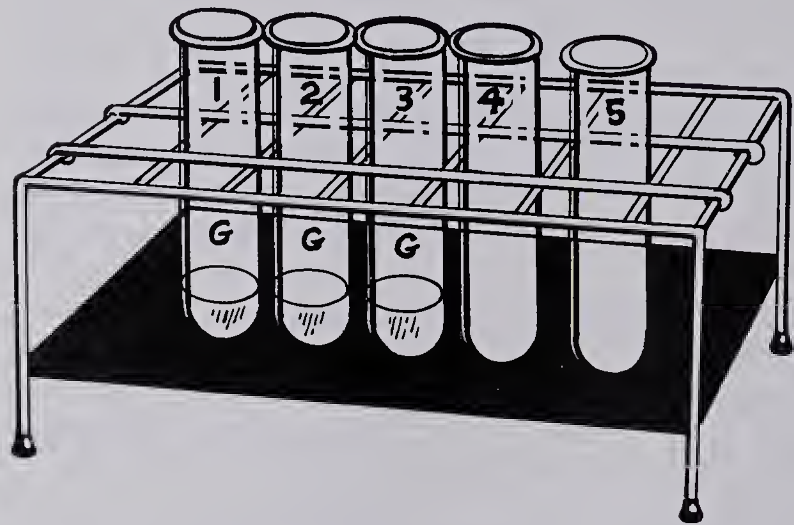
Figure 5–5

- 20 round peas
- 20 wrinkled peas
- 4 small jars, the size of baby food jars
- distilled water, 1 litre
- grease pencil
- 5 test tubes
- test-tube rack
- graduated cylinder, 10-ml or 25-ml
- 5% glucose solution, 20 ml
- mortar and pestle
- piece of clean muslin, bed sheet, or pillow case; at least 20cm x 20 cm
- beaker, 250-ml, or similar size jar
- rubber band
- iodine solution in dropper bottle

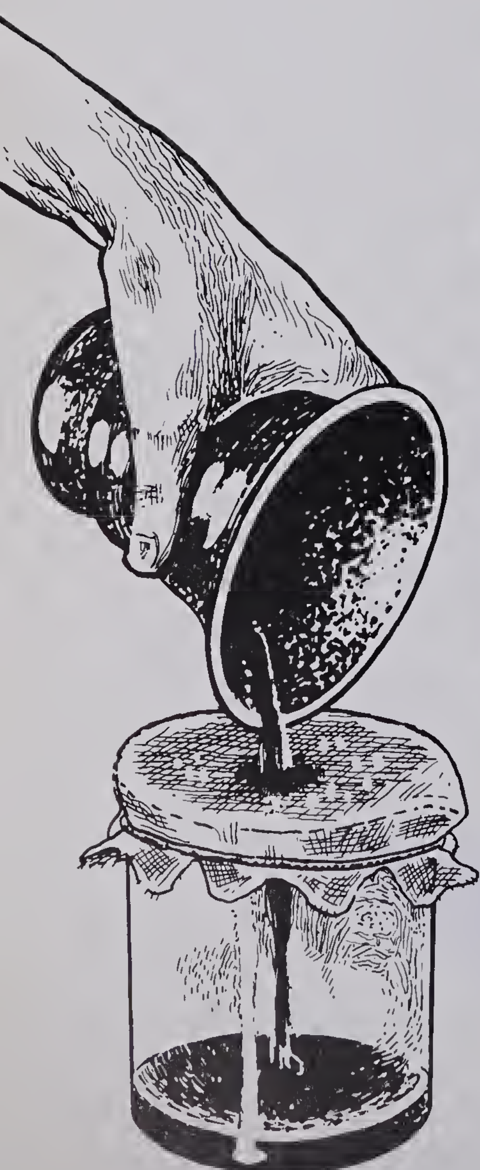
A. Put the round peas in one clean jar and the wrinkled peas in another. Be sure you put the same number of peas in each jar. Use the grease pencil to write your name and the kind of peas (round or wrinkled) on each jar. Then fill the jars with distilled water and set them aside.

IMPORTANT: Let the peas soak overnight; continue the investigation tomorrow.

B. Use the grease pencil to number the test tubes, *1*, *2*, *3*, *4*, and *5*. Write the numbers near the top of the test tubes. Then set the tubes in the test-tube rack. Use the graduated cylinder to put 5 millilitres of glucose solution in Test Tubes 1, 2, and 3. Write *G* for glucose on these tubes.



C. Place the soaked round peas in the mortar. Add 10 millilitres of distilled water. Use the pestle to grind the peas. Grind them until there are no large particles. (This takes a lot of effort.)



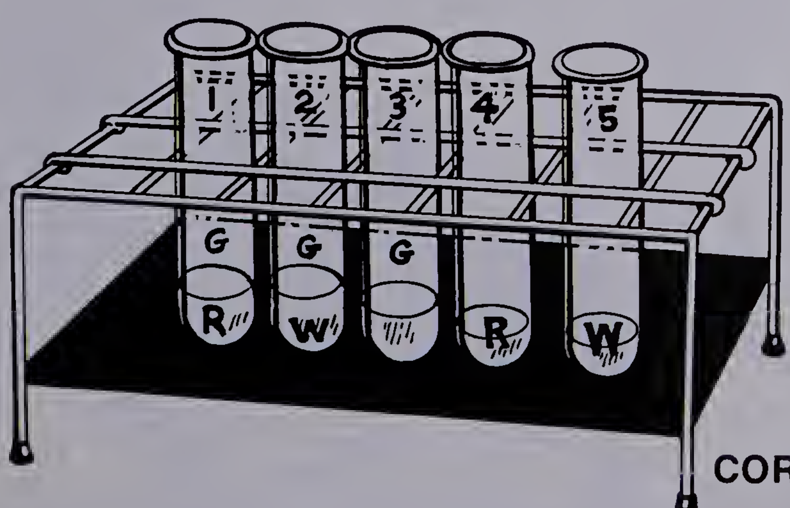
D. Use the rubber band to fasten the piece of muslin over the mouth of the beaker. Take the pea mixture from the mortar and filter it through the cloth into the beaker. The filtered material is called *pea extract.*

✔ 5–4. What is the color of the pea extract?

E. Pour the pea extract into a clean jar. Label the jar *round-pea extract.* Wash the mortar and pestle, the beaker, and the piece of muslin.

F. Repeat Steps C and D for the soaked wrinkled peas. Then pour the pea extract into a clean jar that you labeled *wrinkled-pea extract.*

G. Use the graduated cylinder to put 3 millilitres of round-pea extract into Test Tubes 1 and 4. Label the test tubes *R* for *round-pea extract.* Clean the graduated cylinder and use it to put 3 millilitres of the wrinkled-pea extract into each of Test Tubes 2 and 5. Label the tubes *W* for *wrinkled-pea extract.*



The test tubes should have these solutions.

TUBE NO.	GLUCOSE	PEA EXTRACT
1	5 ml	Round-3 ml
2	5 ml	Wrinkled-3 ml
3	5 ml	0
4	0	Round-3 ml
5	0	Wrinkled-3 ml

In thirty minutes you'll check the test-tube solutions for starch. The procedure is described in Step H. This 30-minute wait is for the starch-forming substance in the extract to act on the glucose. It should change the glucose to starch. But this shouldn't happen in all four tubes.

✔ 5–5. What is the reason for having glucose without a pea extract in Tube 3?

✔ 5–6. What is the reason for having a pea extract without glucose in Tubes 4 and 5?

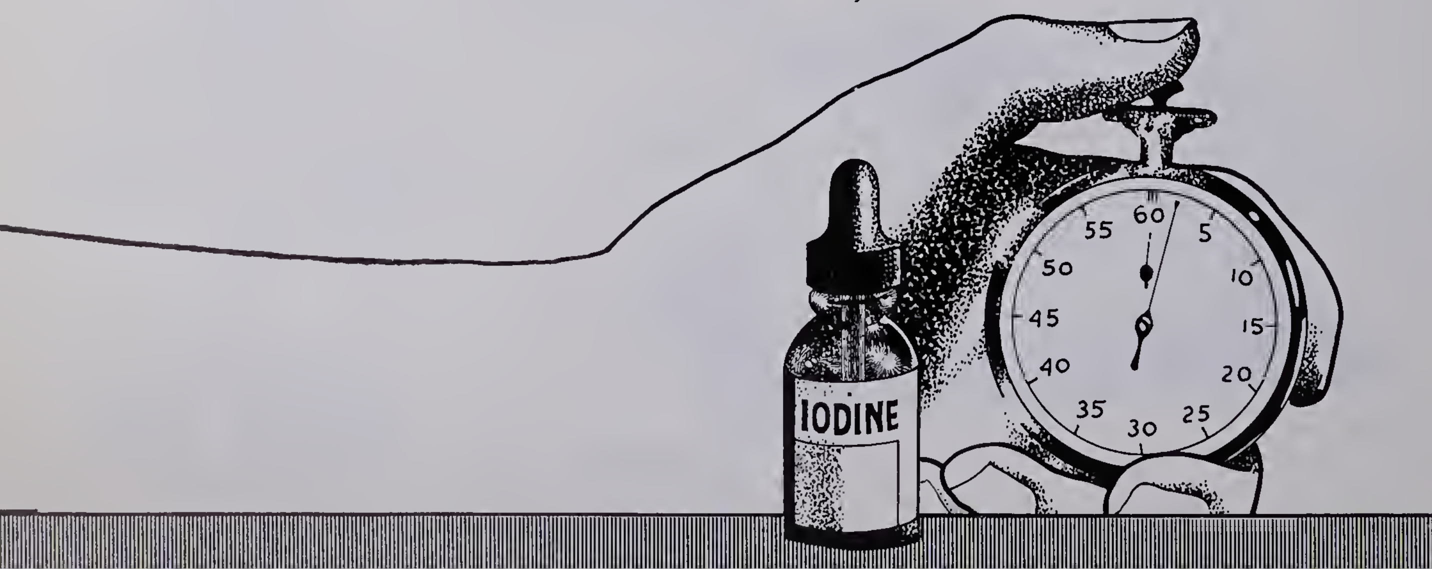
The solutions in Tubes 3, 4, and 5 are *controls*. The solution in Tube 3 is tested to see if glucose alone produces starch. The solution in Tube 4 is tested to see if round-pea extract alone produces starch. The solution in Tube 5 is tested to see if wrinkled-pea extract alone produces starch.

Iodine is used to test for starch. If starch is present in a solution, the iodine will make the solution turn dark blue.

✔ 5–7. Suppose the solution in Tube 3 turns dark blue when iodine is added. What would this mean?

✔ 5–8. In which tubes do you think starch will be produced?

H. After thirty minutes, add one drop of iodine solution to each of the five tubes. Gently shake the tubes to mix the solutions.



✔ 5–9. Which tubes show the presence of starch?

✔ 5–10. Which tube showed the most amount of starch?

✔ 5–11. Which pea, round or wrinkled, has greater starch-making ability?

✔ 5–12. Why didn't Tubes 3, 4, or 5 show the presence of starch?

It's impossible to go back in history to when both round and wrinkled peas produced the same amount of starch. So we can't really be sure that one type is a mutation of the other. But this is the way a mutation behaves. A mutation in the gene that controls starch-making ability could result in the plant's loss of ability to make starch.

As you know, mutations occur in humans as well as plants. When they occur, the affected trait is passed on to following generations. Everyday in the United States, about 700 babies are born with birth defects. These may be mental defects, physical defects, or both. Many are the results of mutations.

Some physical defects may be corrected surgically. Examples of these are clubfoot, cleft palate (the upper part of the mouth is not formed into one piece), polydactyly (extra digits on hands or feet), and hydrocephalus (a large head at birth caused by excessive fluid).

surgical correction of clubfoot

polydactyly

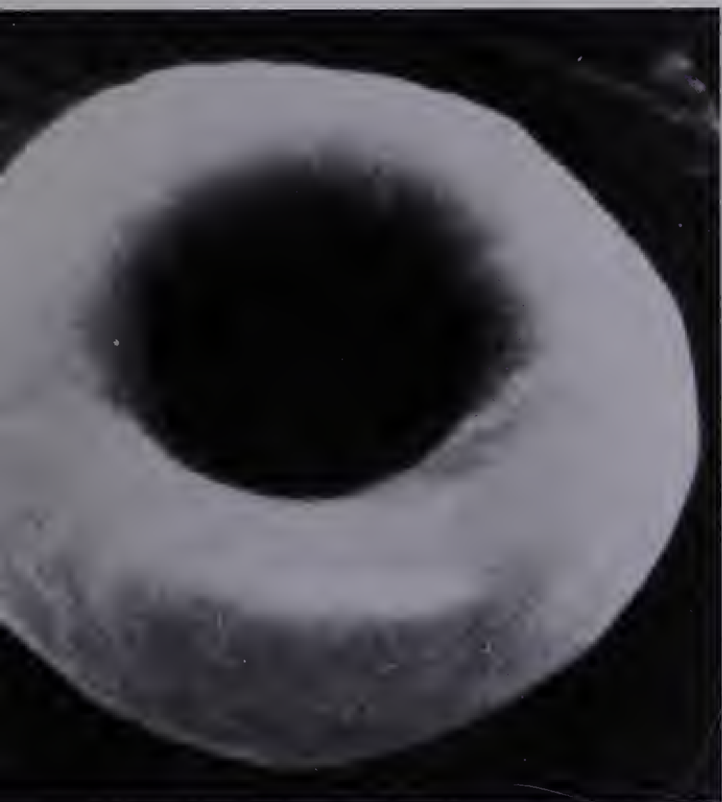
Some inherited diseases can be controlled by diet and medication if recognized early. Examples of these are diabetes (the body is unable to process sugar) and phenylketonuria (substances build up in the body causing brain damage and severe mental retardation).

But some diseases are not curable: Huntington's chorea (loss of muscle control and degeneration of brain), Tay-Sach's disease (blindness, severe mental retardation), and Down's syndrome or mongolism (mental retardation). Some progress is being made for treatment of cystic fibrosis and sickle cell anemia. But the diseases are often fatal.

✓ 5–13. A person who inherits a fatal disease can pass the disease on to future generations. However, this is of little concern for some diseases. Explain why.

Sometimes a very slight change in a gene causes a mutation. Consider sickle cell anemia, for example. In the red blood cells, there are hemoglobin (HEE-mo-glow-bin) molecules that carry oxygen. A gene controls the way these molecules are formed. When the gene undergoes a change, a mutated hemoglobin molecule is produced. When there are too many mutated molecules in the blood cells, the blood cells sickle (change to a sickle shape). See Figure 5–6.

Sickled cells clog blood vessels and interfere with the flow of blood. The body tissues do not get enough oxygen. This causes attacks of severe pain and high fever. The attacks may last several days. Some sickle-cell anemia victims suffer blindness, convulsions, loss of speech, or paralysis. Many die in childhood. Those who survive childhood do not usually live past the age of forty.



normal blood cell

sickled blood cells

Figure 5–6

Mutations may occur at any time, and in any part of your body. For instance, suppose you have normal vision. At this very moment, in one of your body cells, the gene for color vision may change to one for color blindness.

But your color vision probably won't change. The cell in which the mutation occurs might be in your big toe. Each time

the cell divides (as cells do all the time) that gene for color vision will be duplicated. But since it's a "toe cell" the only genes affected are those in your toe.

But suppose there is a mutation in the gene for color vision in a sex cell. If the cell is used in reproduction, the mutant gene could be passed on to the child. Then all the body and sex cells of the child would contain the mutated gene for color blindness.

★ 5–14. If a mutation occurs in a cell in your brain, why won't it be passed on to future generations?

Most mutations are harmful. If a pea can't make starch rapidly, it can't produce food well. As you know, mutations can cause serious diseases. But not all mutations are always bad. For instance, let's consider sickle cell anemia again.

The mutated sickle-cell anemia gene first occurred in regions where malaria was a major disease. (These regions are the shaded areas in Figure 5–7.) The sickle cell condition increased a person's resistance to malaria. So in the presence of malaria, the sickle cell gene might be considered beneficial.

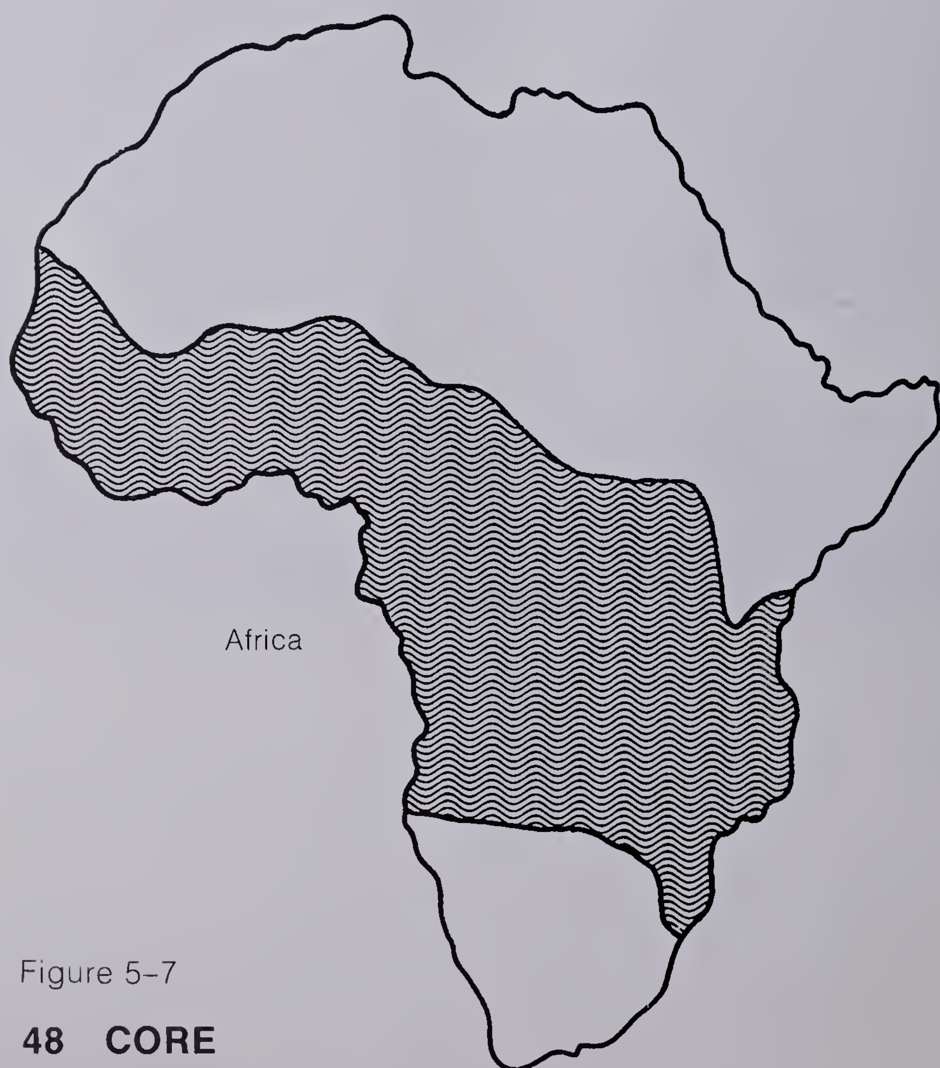


Figure 5–7

The Black people in malarial regions are affected most by sickle cell anemia. However, cases of the fatal disease also have occurred in non-Black people of the regions. In Africa, as many as 40% of the total population have a sickle cell gene. In the United States, about 10% of the Black population have a sickle cell gene. (Most of these people have ancestors from the malarial regions of Africa.) Not everyone with a sickle cell gene has the disease. Some people are carriers of the disease. If two carriers have a child, the child *may or may not* have the disease. If two people with the disease have a child, the child *will* have the disease. Most of these children will die in childhood; few will live past the age of forty.

✔ 5–15. Why might it be a good idea to test people for sickle cells?

Today there are four states that require a test for sickle cell anemia in order to get a marriage license. And there is one state that requires a test for Tay-Sachs disease. Other states may soon have these requirements.

advanced

Activity 6 Planning

Activity 7 Page 52

Objective 14: Name the chemical molecule that makes up genes.

Sample Question: What is the name or abbreviation of the chemical molecule that makes up genes?

Objective 15: Describe how DNA produces differences between species and between individuals.

Sample Question: Which of the following accounts most for genetic differences among living things?
a. the amount of DNA in the cells
b. the number of genes
c. the order of nucleotides in DNA

Objective 16: Describe how DNA duplicates itself.

Sample Question: DNA duplicates itself by
a. dividing and then taking on new nucleotides.
b. producing spores.
c. multiplying and then dividing.

Activity 8 Page 57

Objective 17: Describe how genes and enzymes control the activities of organisms.

Sample Question: Which statement describes the currently accepted hypothesis about the relationship of genes and enzymes?
a. Gene A produces enzyme A and enzyme B.
b. Gene A produces enzyme A, gene B produces enzyme B.
c. Gene A and gene B produce enzyme A.

Activity 9 Page 60

Objective 18: Explain how recessive traits are inherited in dihybrid and trihybrid crosses.

Sample Question: What genes does a YyRr parent contribute to the offspring?

a. Either Yy or Rr
b. Either YR, Yr, yR, or yr
c. Either YY, yy, RR, or rr

Objective 19: Tell whether or not a hybrid shows a dominant trait.

Sample Question: A pure strain plant with red flowers is crossed with a pure strain plant with white flowers. If all the offspring have pink flowers, then

a. red flower-color is a dominant trait.
b. red flower-color is a recessive trait.
c. flower color is not a dominant trait in this plant.

Answers
14. Deoxyribonucleic acid (DNA) 15. c 16. a 17. b 18. b 19. c

Activity 7

DNA

In 1865, Gregor Mendel discovered the generation link. He proposed that heredity is passed on by links (genes) in the reproductive cells. But this theory went unnoticed for many years.

By the early 1900s, there was more interest in genes and heredity. However, no one knew what made up a gene. Also by 1900, a chemical called *deoxyribonucleic* (dee-OK-see-rye-bo-new-klee-ik) *acid*, or DNA, had been found in cells. No one knew how important DNA was. No one suspected that there was any connection between genes and DNA.

Then an experiment was done with bacteria cells. The experiment linked DNA with heredity. Two different strains of bacteria were investigated. One of these strains caused pneumonia in mice; the other didn't.

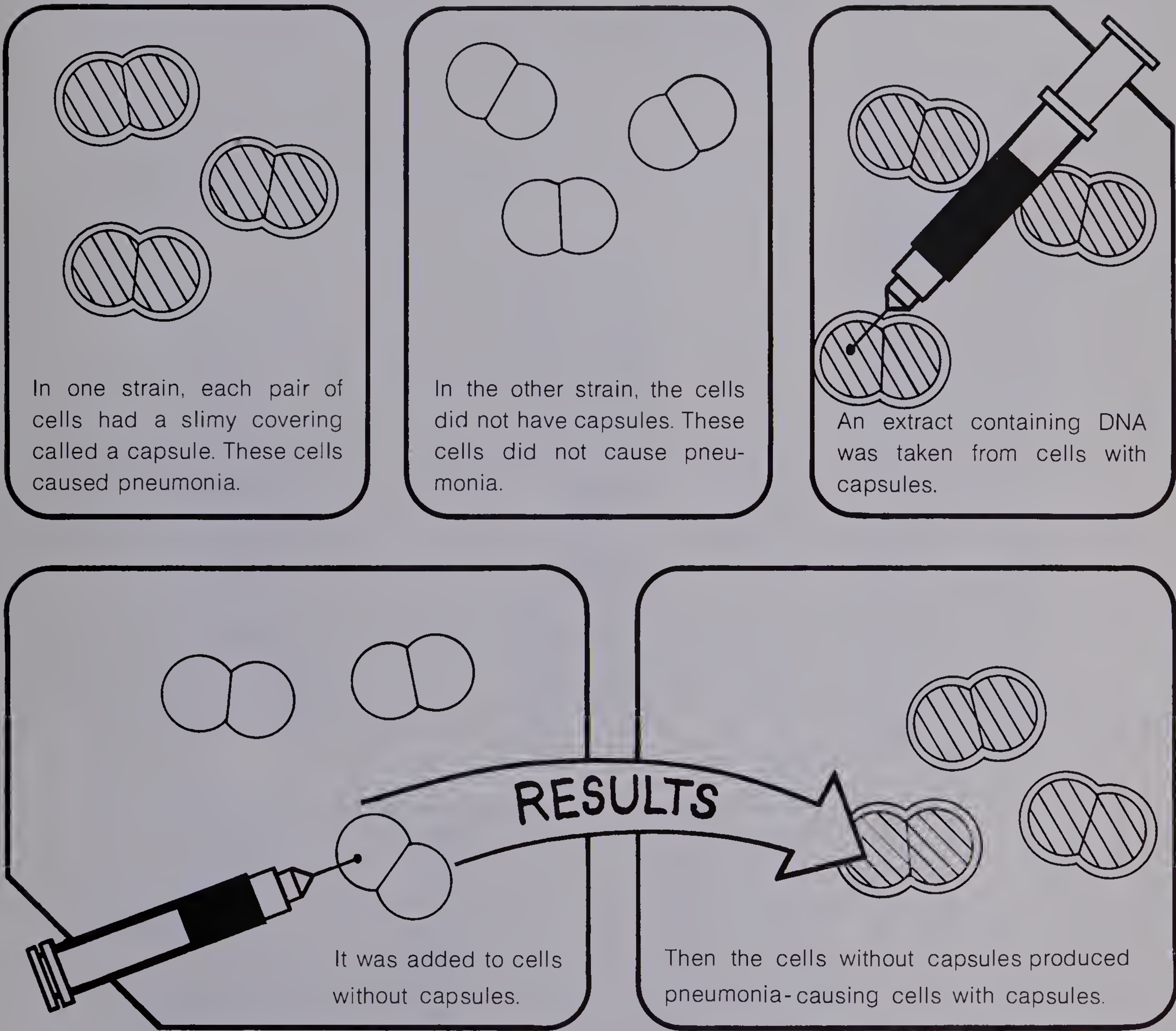


Figure 7–1

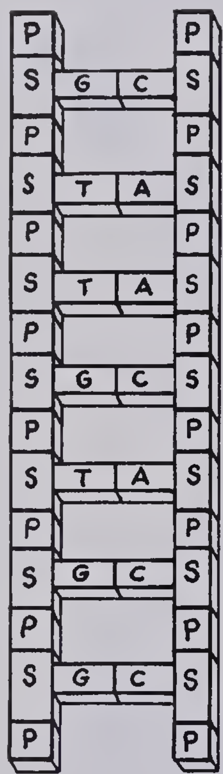
It is now believed that genes are made up of DNA molecules. In 1953, an American biologist, James Watson, and a British biologist, Francis Crick, made a model of the DNA molecule. They used the model to explain what DNA is and how it works.

★ **7–1. What do the letters *DNA* stand for?**

The DNA molecule is made up of three kinds of smaller molecules:

1. sugar molecules called *deoxyribose* (dee-ok-see-RYE-bose)
2. phosphate molecules called *phosphoric* (fos-FOR-ik) *acids*
3. base molecules called *thymine* (THIGH-meen), *guanine* (GWON-een), *adenine* (AD-en-een), and *cytosine* (SIGHT-oh-seen).

Watson and Crick made the model of the DNA molecule in the shape of a double helix (HEE-liks). This is like a ladder that has been twisted from the top but not at the bottom (Figure 7–2).



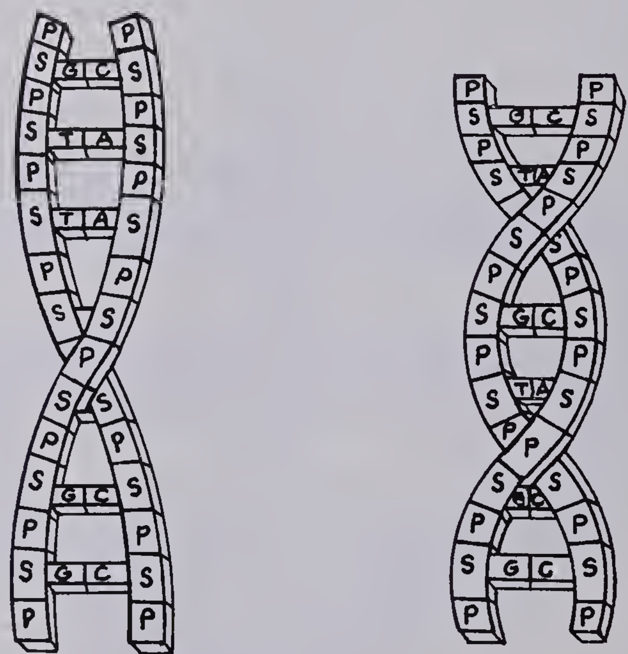


Figure 7–2

Study Figure 7–2 as you read the following description. The uprights, or sides, of the DNA ladder are made of sugar (S) molecules and phosphate (P) molecules. Each rung of the ladder is made up of two base molecules. The base molecules can pair off only in these ways: adenine (A) with thymine (T) and guanine (G) with cytosine (C). This is illustrated in Figure 7–3.

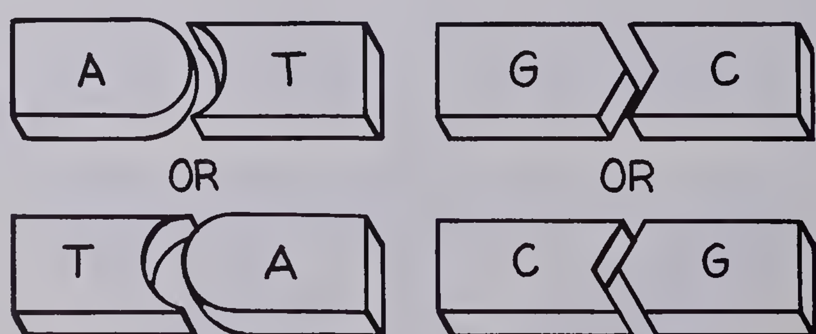


Figure 7–3

✓ 7–2. In Figure 7–4, a section of the DNA ladder is shown. Make a rough sketch of it. Then name the bases that are not named. Use *A* for adenine, *C* for cytosine, *G* for guanine, and *T* for thymine.

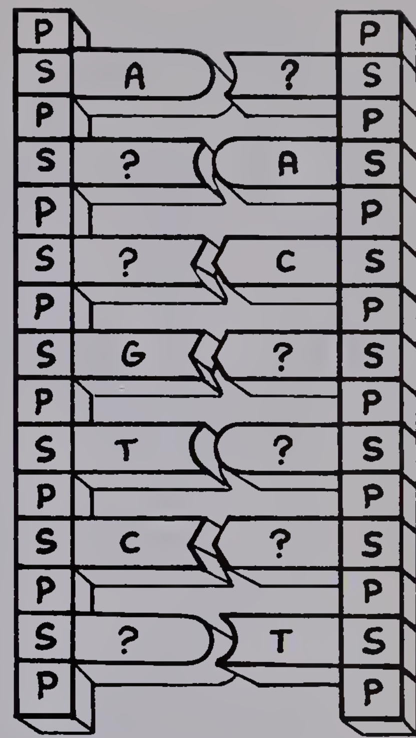


Figure 7–4

The ladder actually consists of chains of nucleotides (NEW-klee-oh-tides). Each nucleotide has a phosphate molecule, a sugar molecule, and a base molecule. In Figure 7–5, a thymine nucleotide is shown.

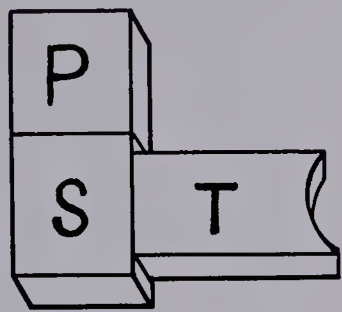


Figure 7–5

The DNA ladder consists of two halves or strands. The order of nucleotides in each strand varies for each type of organism. The order of the nucleotides in bacteria is different from that in chickens or humans or any other organism. The sugar and phosphate molecules, the sides of the ladder, are always in the same order. The base molecules are what change.

In Figure 7–6, parts of three nucleotide chains are shown. Each combination is different from the others. A nucleotide alphabet is used to refer to strands. The strands in Figure 7–6 are made up of the nucleotide "words" *T-T-T, G-C-G-C,* and T-G-A.

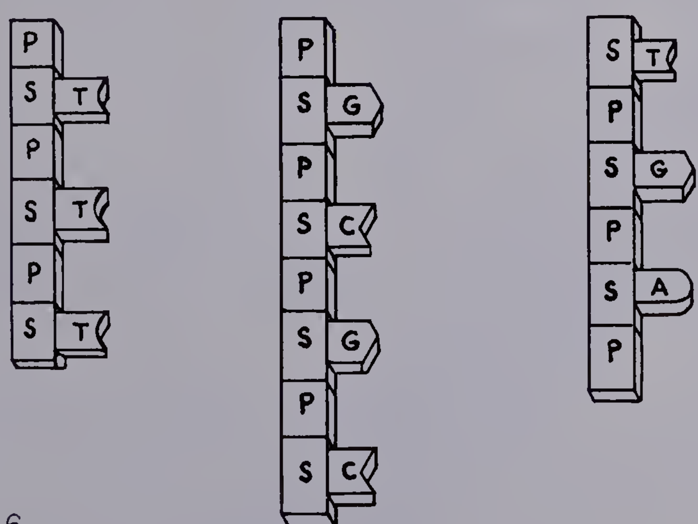


Figure 7–6

★ **7–3. If you had to tell two different DNA molecules apart, what would you check for?**

The DNA molecule must duplicate itself exactly. The model of DNA provides an explanation of how this duplication happens.

Look at Figure 7–7. It shows a sample DNA molecule with six pairs of bases in the rungs. (An actual DNA molecule may have as many as 20,000 bases.) The pairs of bases are held together by weak chemical bonds. During duplication, the bonds act like a zipper. Starting at one end of the molecule, the bases are unzipped, one at a time. (See Figure 7–8.) Finally, the two strands are separated.

Remember, DNA molecules are located in every cell. Also stored in a cell are "free" nucleotides (Figure 7–9). When the strands of the DNA molecule are "unzipped," the "free" nucleotides pair off with the nucleotides in each unzipped strand. The adenine (A) and thymine (T) nucleotides pair off; the guanine (G) and cytosine (C) nucleotides pair off. Finally, each separated strand becomes paired off. The duplication is complete. The DNA molecule has duplicated itself exactly.

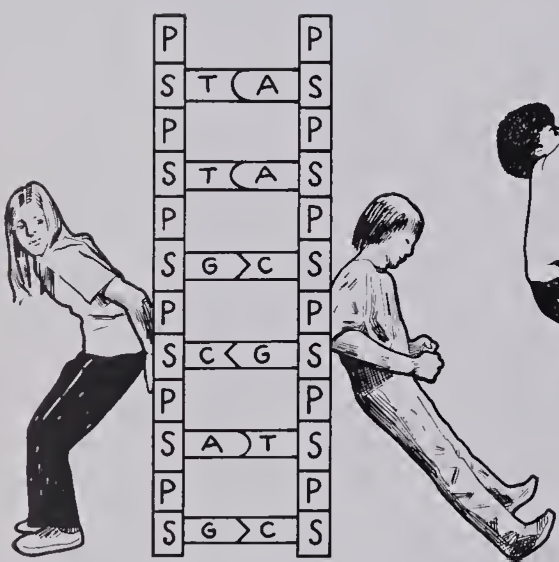


Figure 7–7

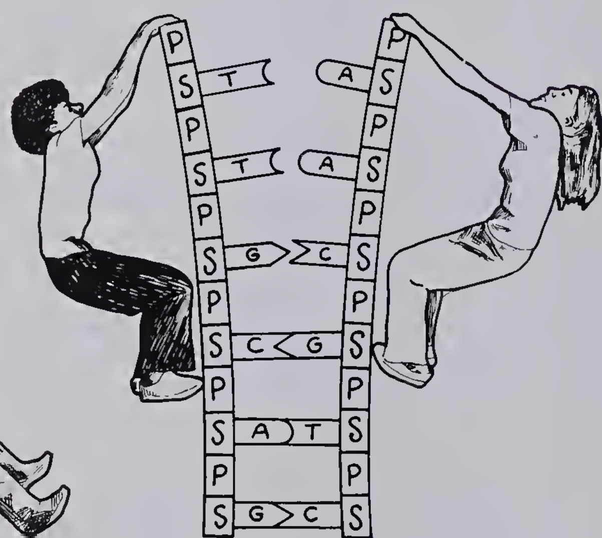


Figure 7–8

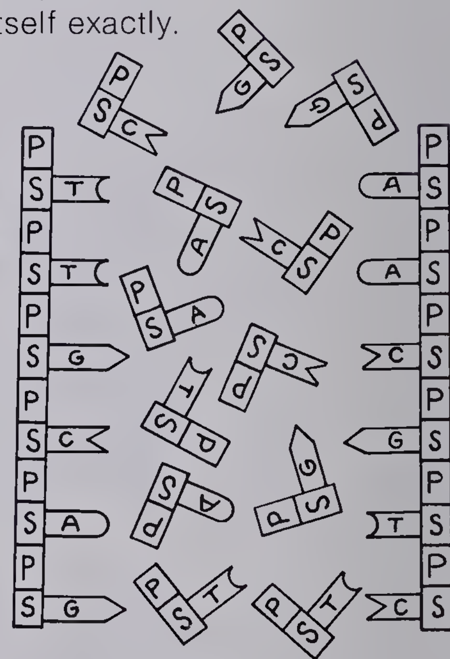


Figure 7–9

★ 7–4. In your notebook, sketch the two strands of DNA that are shown in Figure 7–9. Then draw the nucleotides that complete the two molecules. Use the nucleotide alphabet to label all the molecules.

★ 7–5. Look at the two DNA molecules that you drew for Question 7–4. How do they compare with the original DNA molecule shown in Figure 7–7?

Cells divide (reproduce themselves) all the time. Each time this happens, the DNA molecules duplicate themselves. This duplication process is an essential activity of genes.

In Control

Genes control almost everything about an organism: its growth, its development, and its functioning. The actions of a gene are difficult to trace in a complex organism like a human being. It's much easier to use a fairly simple organism like a fungus or mold. In the 1940s two scientists, George W. Beadle and Edward L. Tatum, experimented with a pink mold. The mold is called *Neurospora* (new-ROSS-po-rah). These men studied the actions of genes in Neurospora. Their findings were very important. In fact, the men were awarded part of the Nobel prize in medicine and physiology.

Beadle and Tatum knew that Neurospora grows rapidly in a simple medium made of salts, sugar, and the vitamin, biotin. They also knew that Neurospora is made of proteins, carbohydrates, fats, vitamins, and nucleic acids. Nucleic acids are very complex chemical compounds including 20 *amino* (uh-MEE-no) acids.

8–1. Neurospora uses only a simple medium for growth. Yet the chemicals in Neurospora are very complex. Where do you think the complex chemicals come from?

It seems that Neurospora has the ability to make complex chemicals from simple substances. This is a task that humans cannot do. Instead, we must get the complex materials from our diet. Beadle and Tatum wanted to know if genes controlled this ability. They decided to mutate (change) the Neurospora's genes. They did this by exposing Neurospora to X rays.

8–2. How do you think the X rays affected the genes of the mold?

8–3. How do you think the X rays affected future generations of the mold?

8–4. How would you know if mutations were passed on to future generations of the X-rayed mold?

Beadle and Tatum found that the X-rayed mold could not grow in the simple medium. But the mold did grow in a complete medium. The complete medium contained all the amino acids, vitamins, and other complex chemicals found in Neurospora (Figure 8–1).

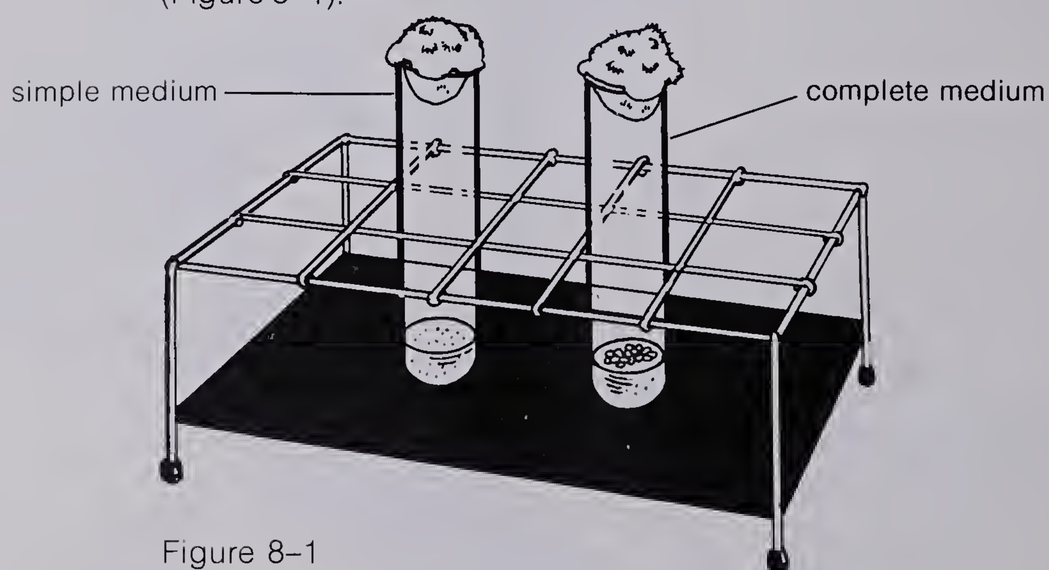


Figure 8–1

8–5. What would you predict about the offspring of the mutant mold?

8–6. What can you infer about the mutant mold? Remember, neither the mold nor its offspring can grow in the simple medium.

Beadle and Tatum wanted to isolate the chemicals needed to make the mutant mold grow. These isolated chemicals would be the ones that the mold was not making for itself.

Separate bits of the mutant mold were put into different substances. Each substance had the simple medium plus one extra chemical, such as an amino acid or a vitamin (Figure 8–2).

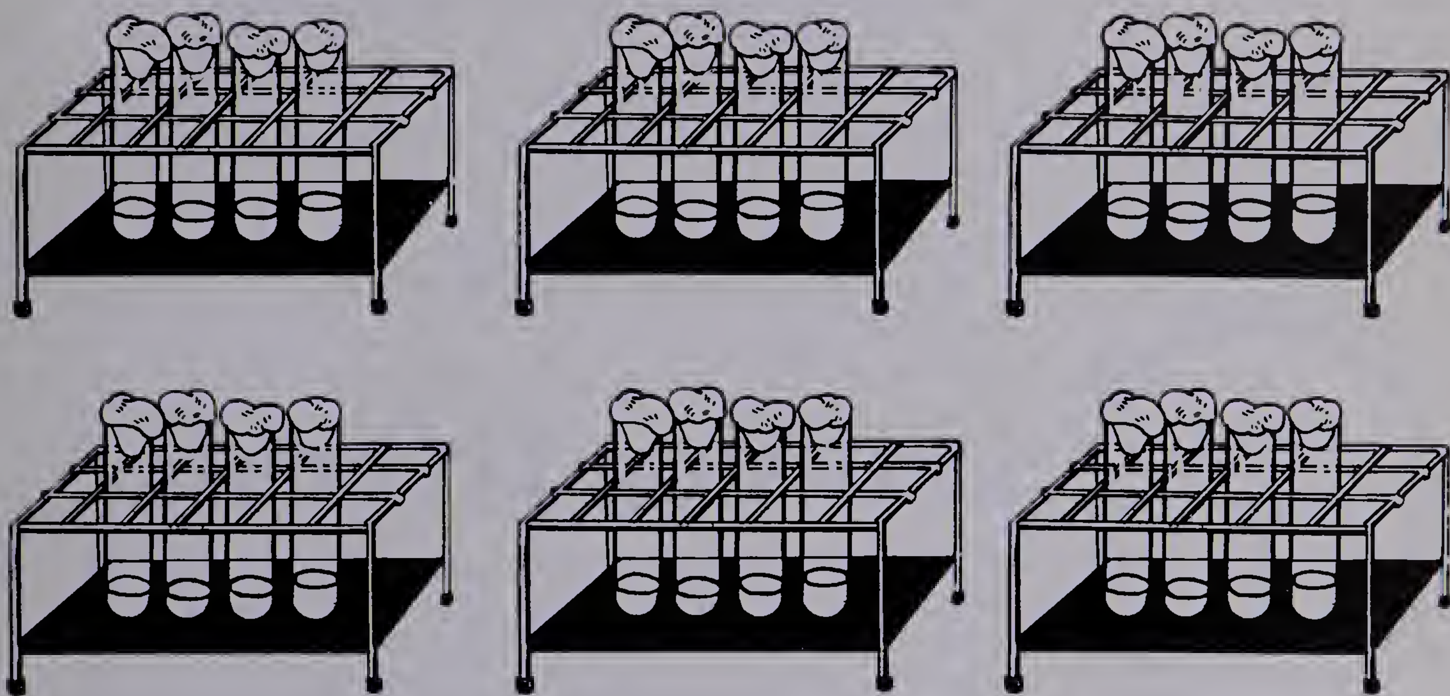


Figure 8–2

8–7. Suppose the mold would not grow unless chemical A was added. What can you conclude about the mold?

Beadle and Tatum found that the mutated Neurospora grew in only one of the tubes. This tube contained the simple medium plus the amino acid, arginine (ARE-juh-neen). So, after exposure to X rays, the mold stopped producing arginine. Beadle and Tatum reasoned that the ability to produce arginine was lost when the gene was mutated. When the gene changed, the ability changed. This was evidence that genes control the ability to make complex chemicals from simple substances.

Biologists found that complex chemical reactions take place in cells only when *enzymes* (EN-zeyems) are present. An enzyme is a chemical that can speed up a chemical reaction. You have probably learned about enzymes in pea plants. For example, there is a substance in wrinkled peas that causes glucose to turn into a complex starch. This transformation is speeded up by an enzyme in the peas.

8–8. An extract from round peas does not form starch from glucose rapidly. An extract from wrinkled peas does. What do you think is the reason for this?

There is an hypothesis about genes and enzymes. It's called the one-gene one-enzyme hypothesis. That is, each gene is responsible for the production of a specific enzyme. If the gene is changed (mutated), the enzyme is changed.

★ **8–9. Suppose the tallness of a pea plant is caused by a simple enzyme. How many genes control the plant's tallness?**

Some of the complex chemicals made in Neurospora are made, in the same way, in humans. By studying mold, we learn about our own bodies.

Crossing Hybrids

Gregor Mendel studied heredity by experimenting with pea plants. At first he investigated one trait at a time. He performed hybrid crosses and studied the offspring. (A hybrid cross involves one trait.) Then he performed dihybrid crosses involving two traits. In one experiment, he crossed pea plants having yellow round peas and pea plants having green wrinkled peas. Each of the plants were pure strain for both traits.

A pure strain plant having yellow round peas has the genes *YYRR*. A pure strain plant having green wrinkled peas has the genes *yyrr*. When the plants are crossed, each plant gives one gene from each pair to the offspring (Figure 9–1).

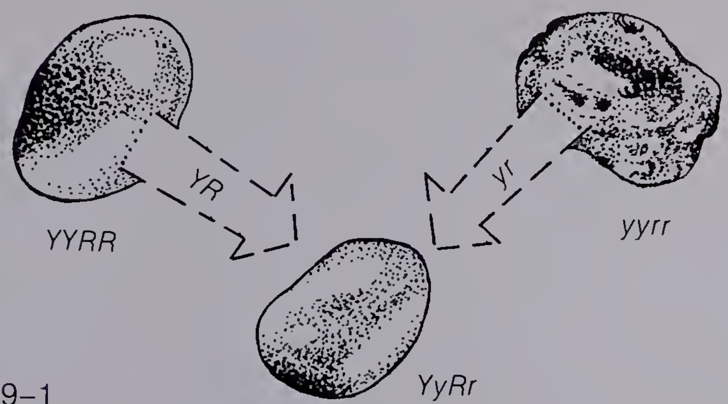


Figure 9–1

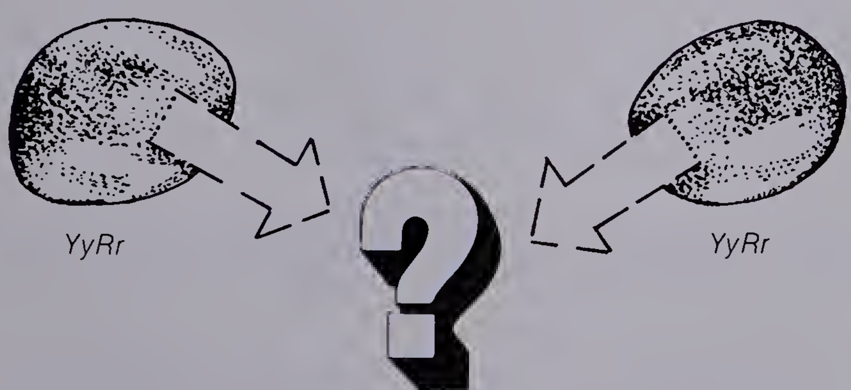
✔ 9–1. What genes come from the parent with yellow round peas?

✔ 9–2. What genes come from the parent with green wrinkled peas?

✔ 9–3. What genes do the offspring have?

✔ 9–4. What do the offspring's peas look like?

Mendel crossed offspring from the first dihybrid cross. The plants crossed had yellow round peas *(YyRr)*.



✔ 9–5. What are the possible gene combinations that each plant *(YyRr)* can give to the offspring? (A combination consists of one gene from the *Yy* pair and one gene from the *Rr* pair.)

Each offspring could have any one of sixteen gene combinations. Each combination has two pairs of genes. The grid in

Figure 9–2 shows the possible combinations. At the top of the grid are the genes that one parent can contribute. We'll call this parent the "first parent." The left side of the grid are the genes that the "second" parent can contribute.

FIRST PARENT

SECOND PARENT	*YR*	*Yr*	*yR*	*yr*
YR	*YYRR*	*YYRr*	*YyRR*	*YyRr*
Yr	*YYRr*	*YYrr*	*YyRr*	*Yyrr*
yR	*YyRR*	*YyRr*	*yyRR*	*yyRr*
yr	*YyRr*	*Yyrr*	*yyRr*	*yyrr*

Figure 9–2

✔ 9–6. How many gene combinations are there for yellow peas? Remember, yellow (*Y*) is dominant over green (*y*). How many gene combinations are there for green peas?

✔ 9–7. What's the ratio of yellow-pea combinations to all possible combinations? (A ratio is used to compare one number with another. In this activity, we'll express a ratio as a fraction.) What's the ratio of green-pea combinations to all possible combinations?

✔ 9–8. How many gene combinations are there for round peas? How many for wrinkled peas?

✔ 9–9. What is the ratio of round-pea combinations to all possible combinations? Of wrinkled-pea combinations to all possible combinations?

The ratio of yellow-pea combinations to all possible combinations is 12/16 or 3/4. The ratio of round-pea combinations to all possible combinations is 12/16 or 3/4. This means that the probability (chance) of an offspring having yellow peas is 3/4. The probability of an offspring having round peas is 3/4. What is the probability that an offspring will have *both* yellow *and* round peas? To find the answer, one of the principles (rules) for probability is used.

To find the probability that two different events will happen at the same time, multiply the probabilities of each event happening separately.

Probability of offspring having yellow peas:

$$\frac{3}{4}$$

Probability of offspring having round peas:

$$\frac{3}{4}$$

Probability of offspring having *yellow round* peas:

$$\frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$$

There are 9 chances out of 16 that an offspring will have yellow round peas.

✔ 9–10. Look at the chart in Figure 9–2. How many gene combinations are there for a plant with yellow round peas? What is the ratio of yellow-round pea combinations to all possible combinations?

✔ 9–11. How does your answer for Question 9–10 compare with the answer obtained by using the probability principle?

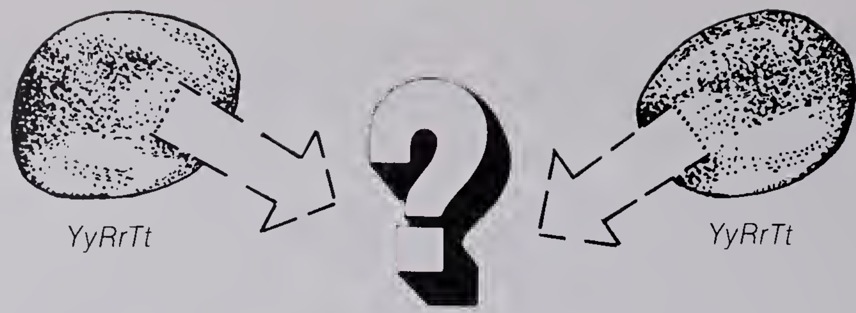
In a hybrid crossing, 3/4 of the gene combinations show a dominant trait, and 1/4 show the recessive trait. These ratios apply to the dihybrid crossing: 3/4 of the peas show the dominant trait, yellow, and 1/4 shows the recessive trait, green; 3/4 shows the dominant trait, round; and 1/4 show the recessive trait, wrinkled.

★ **9–12. What is the probability that offspring from a dihybrid-cross will have peas that are green *and* wrinkled?**

Check the chart in Figure 9–2. Find the ratio of green wrinkled pea combinations to all possible combinations. This ratio should be the same as your answer to Question 9–12.

✔ 9–13. What is the probability that an offspring will have yellow wrinkled peas?

✔ 9–14. What is the probability that an offspring will have green round peas?



Now suppose we cross pea plants that are hybrid for three traits. This is a trihybrid cross. Suppose also that the traits are pea color, yellow (Y) or green *(y);* pea shape, round *(R)* or wrinkled *(r),* stem length, tall *(T)* or short *(t).* The capital letters show the dominant traits.

✔ 9–15. What is the probability that the offspring will have yellow, round peas and tall stems? (Remember, in a hybrid crossing, 3/4 of the offspring show the dominant trait, 1/4 show the recessive trait.)

Mendel studied seven traits in peas. All seven clearly had dominance: yellow pea color was dominant over green; round pea shape was dominant over wrinkled. Later, in other investigations, scientists found many traits that showed complete or almost complete dominance. However, in a number of cases, a clear dominance did not appear. Hybrid offspring resembled neither parent. Instead, the offspring were somewhat like both parents.

Red and white snapdragons behave this way (Figure 9–3). A pure strain snapdragon with red flowers is crossed with a pure strain snapdragon with white flowers. The genes are *RR* (red) and *rr* (white).

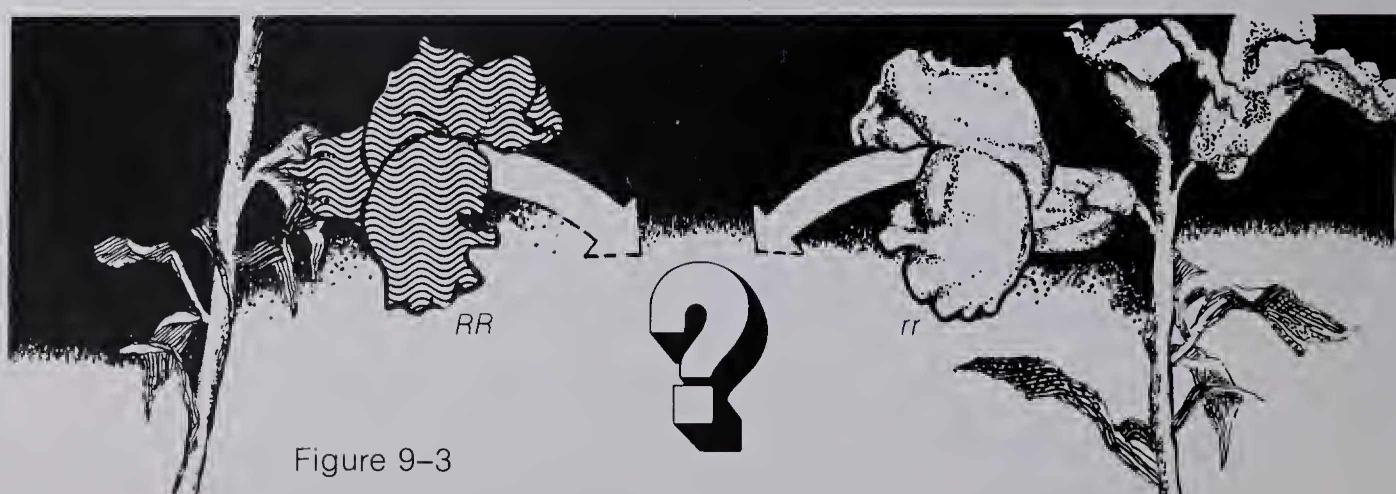


Figure 9–3

✔ 9–16. What genes for color will the offspring have?

If you were to predict the color of the offspring, you would probably say red. Up to now, the offspring of two different pure strain plants all looked like the dominant parent. But with the snapdragons, the offspring were pink; a blend of the two colors. Neither color, red nor white, is dominant.

Now let's investigate the offspring from two pink flowered snapdragons *(Rr)*. In your notebook, draw a grid like the one in Figure 9–4. Complete the grid by writing the correct gene combination in each square: *RR, Rr,* or *rr*. Then, in each square, write the color (red, pink, white) for each combination.

FIRST PARENT

SECOND PARENT	*R*	*r*
R		
r		

Figure 9–4

✔ 9–17. What are the chances that the offspring's flowers will be red? White? Pink?

Now consider a crossing of snapdragons having two traits. One trait shows dominance and the other does not. Here's a description of the crossing:

A pure strain plant with red, normal-shaped flowers *(RRNN)* is crossed with a pure strain plant with white, abnormal-shaped flowers *(rrnn)*. All the offspring have pink, normal-shaped flowers *(RrNn)*, as in Figure 9–5.

Figure 9–5

9–18. Explain why all the offspring have normal-shaped flowers.

Now consider the crossing of two hybrid offspring having pink, normal-shaped flowers *(RrNn)*. Determine the inheritance of these traits. You may want to use a grid like the one in Figure 9–6. Draw it in your notebook. To distinguish the parents, one is called "First" and the other, "Second." Figure out the four possible gene combinations that each parent may give to an offspring. (Each combination will have two genes.) Write these combinations for each parent. Then complete the grid. Find all the possible combinations that can be inherited. In each box, you may want to write what the offspring's flower looked like. If you have trouble, refer to crossings discussed earlier in this activity.

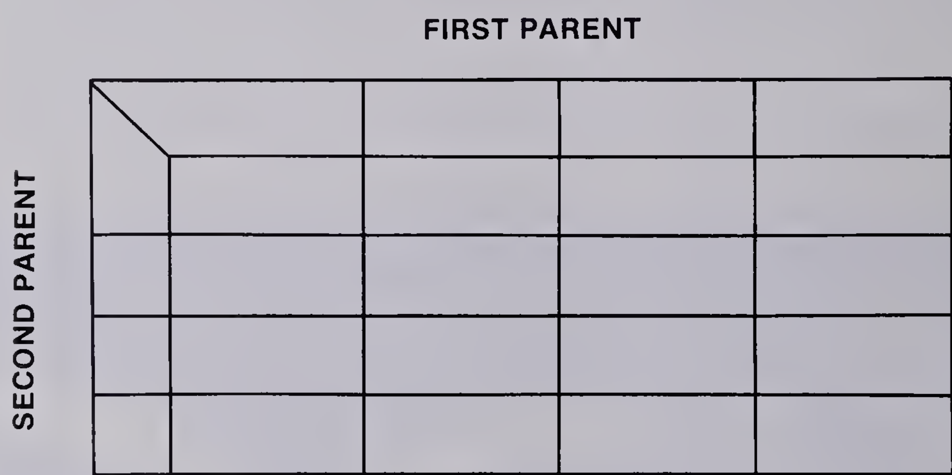


Figure 9–6

9–19. What are the chances that an offspring will have a normal-shaped flower? An abnormal-shaped flower?

9–20. Compare your answers to Question 9–19 with your answers to Question 9–9. The ratios should be the same. Why?

9–21. What are the chances that an offspring will have a red flower? A pink flower? A white flower?

★ **9–22. Suppose you crossed pink-flowered snapdragons with other snapdragons. Suppose half the offspring had pink flowers and half had the same color flowers, but not pink. What color flowers did the parents have?**

excursion

Activity 10 Planning

A Pocketful of Genes

Activity 11 Page 68

There are certain genes that can be identified. They control recognizable traits. In this activity, you'll find out what percentage of your classmates have some of these recognizable traits.

What Advice Would You Give?

Activity 12 Page 70

Should a young man and young woman get married if they are first cousins? Why or why not? You'll read Cindy's advice and then get a chance to write your own.

What's Your Type?

Activity 13 Page 71

Did you ever wonder how blood is typed and why it is typed? You'll find out in this activity.

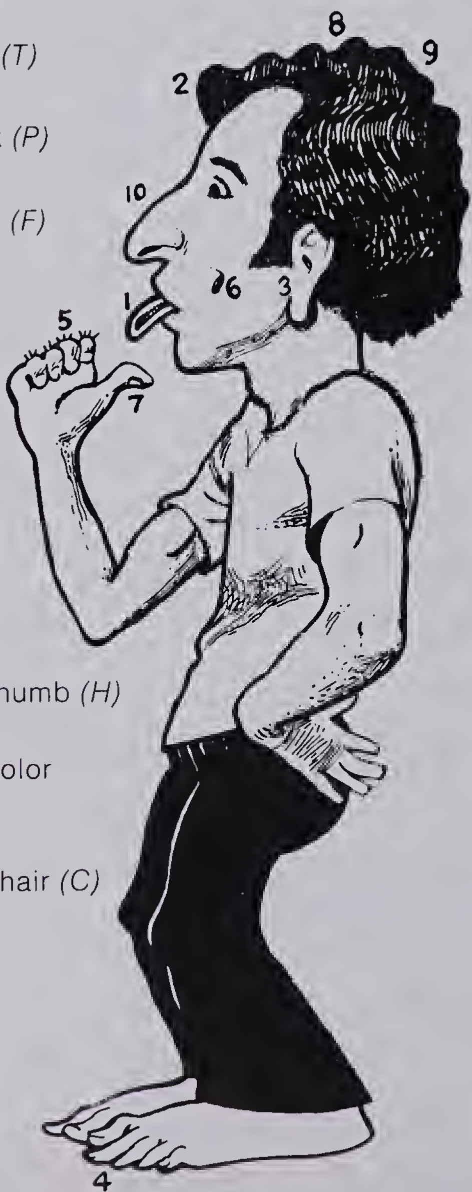
Activity 11

A Pocketful of Genes

We would solve many problems if we could identify all our genes. This is not yet possible. There are too many (a pocketful of) genes. But it is possible to identify genes that control easily recognizable traits.

TRAITS

DOMINANT	RECESSIVE
1. Tongue roller *(T)*	**1.** Not a tongue roller *(t)*
2. Widow's peak *(P)*	**2.** Straight hairline *(p)*
3. Free earlobes *(F)*	**3.** Attached earlobes *(f)*
4. Second toe longer than big toe *(L)*	**4.** Second toe not longer *(l)*
5. Hair on mid-digital knuckle *(H)*	**5.** No hair *(h)*
6. Dimples *(D)*	**6.** No dimples *(d)*
7. Hitchhiker's thumb *(H)*	**7.** No hitchhiker's thumb *(h)*
8. Natural hair color dark *(D)*	**8.** Natural hair color light *(d)*
9. Natural curly hair *(C)*	**9.** Straight hair *(c)*
10. High convex nose *(N)*	**10.** Straight or concave nose *(n)*



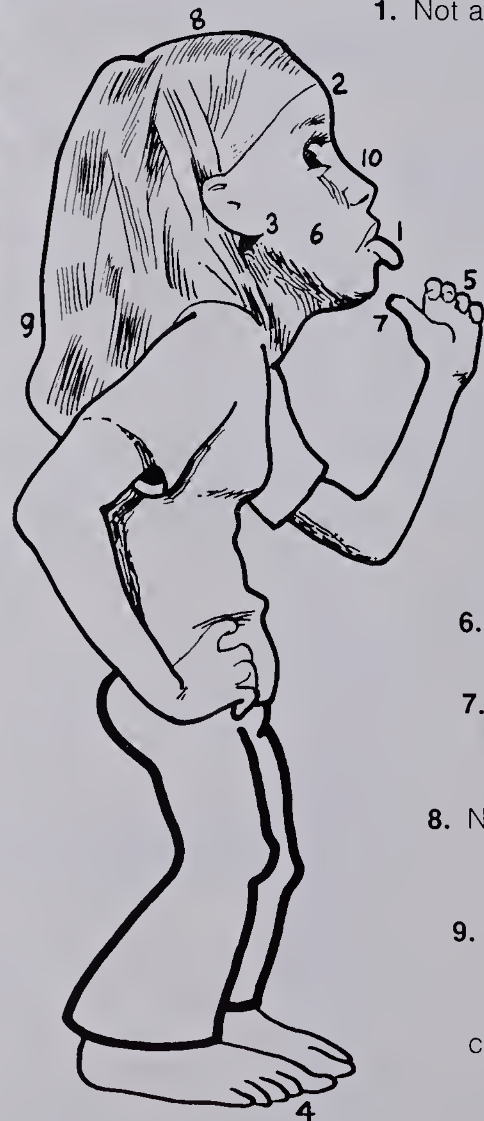
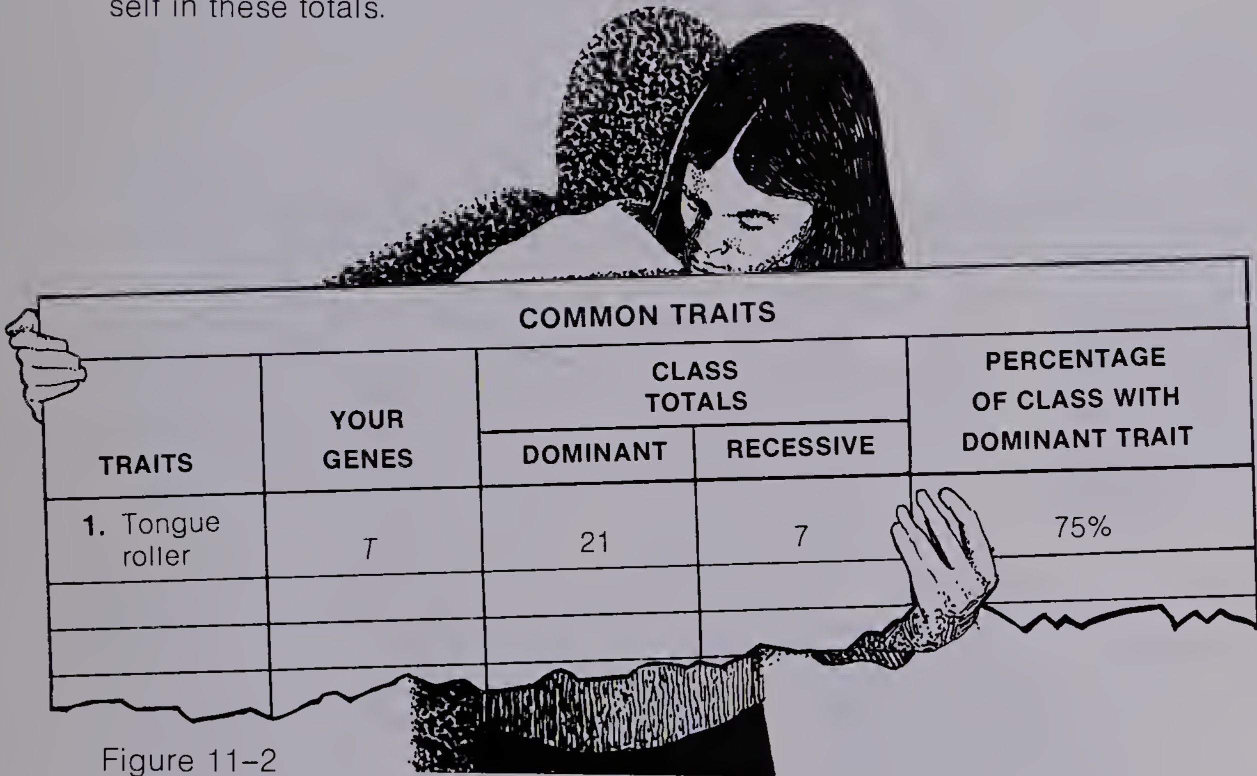


Figure 11–1

Some traits that are thought to be inherited are listed in Figure 11–1. Choose eight or more that you would like to follow. Then draw a chart. List the traits to be studied, your genes for the traits, and how many of your classmates do or do not have the trait.

Part of a chart is shown in Figure 11–2. It is an example of one you might draw. The last column at the right shows the percentage of students who have the dominant trait. To find the percent, divide the number of students having the dominant trait by the number of students tested. Remember to include yourself in these totals.



COMMON TRAITS				
TRAITS	YOUR GENES	CLASS TOTALS		PERCENTAGE OF CLASS WITH DOMINANT TRAIT
		DOMINANT	RECESSIVE	
1. Tongue roller	*T*	21	7	75%

Figure 11–2

Look at the data for "tongue roller" in Figure 11–2. There are 21 students (including the "tester") who have the dominant trait. In all, there were 28 students tested (21 with the dominant trait and 7 with the recessive trait). The percentage of students with the dominant trait is:

$$21 \div 28 = 0.75 \text{ or } 75\%$$

✔ 11–1. How many dominant traits do you have? How many recessive traits do you have?

✔ 11–2. Which of the traits listed in Figure 11–1 seems to be the most common among your classmates?

★ 11–3. Choose one dominant trait from Figure 11–1. What percentage of your class has that trait?

Activity 12 What Advice Would You Give?

ADVICE *By Cindy*

DEAR CINDY: Greg and I are first cousins and were brought up together. We lived in the same neighborhood and went to the same schools. In high school Greg and I often went to parties and dances together. In fact we were together almost every day.

Now Greg and I are going to the same college and are still together constantly. We are in love. We plan to get married and have children. Our state allows first cousins to marry.

My question concerns the children we hope to have. Will they be healthy? Is there any way we can find out?

E.B.

Dear E.B.: Some relationships like yours have produced healthy, normal children; others have produced children who have inherited diseases.

If there is a history of diabetes, epilepsy, or other inherited diseases in either family, I would recommend genetic counseling. If there is no such history, the children could be perfectly normal.

★ **12–1. In your notebook, draw the family tree for the young couple in the article. If you need help in drawing a family tree, refer to Activity 3.**

✔ 12–2. Which relatives do the cousins have in common?

✔ 12–3. How are the young woman and young man related?

Diabetes, the disease mentioned in the article, is a serious condition that is fatal if it is not treated. It is caused by the malfunction of the pancreas, an organ of the body. Normally, part of the pancreas produces a substance called insulin. The insulin regulates the use of sugar in the body. In a diabetic person, the pancreas does not produce insulin; the use of sugar in the body is not regulated. Too much or too little sugar in the body causes illness and often death.

Diabetes cannot be cured at present. But it can be treated. Pills or shots provide insulin or stimulate its production.

A common type of diabetes is probably inherited. But the gene, or genes, causing the disease are not known. Geneticists believe diabetes is probably caused by a recessive gene (or genes).

✔ 12–4. Assume that neither of the couple's parents or grandparents had diabetes. Does this mean that the young man and woman do not have the gene for the diaease? Explain your answer.

✔ 12–5. Write a reply to "E.B." giving your advice. In your reply, explain why it is difficult to detect recessive hereditary diseases. List some of the diseases thought to be hereditary. (You may want to review the diseases discussed in Activity 5.)

What's Your Type?

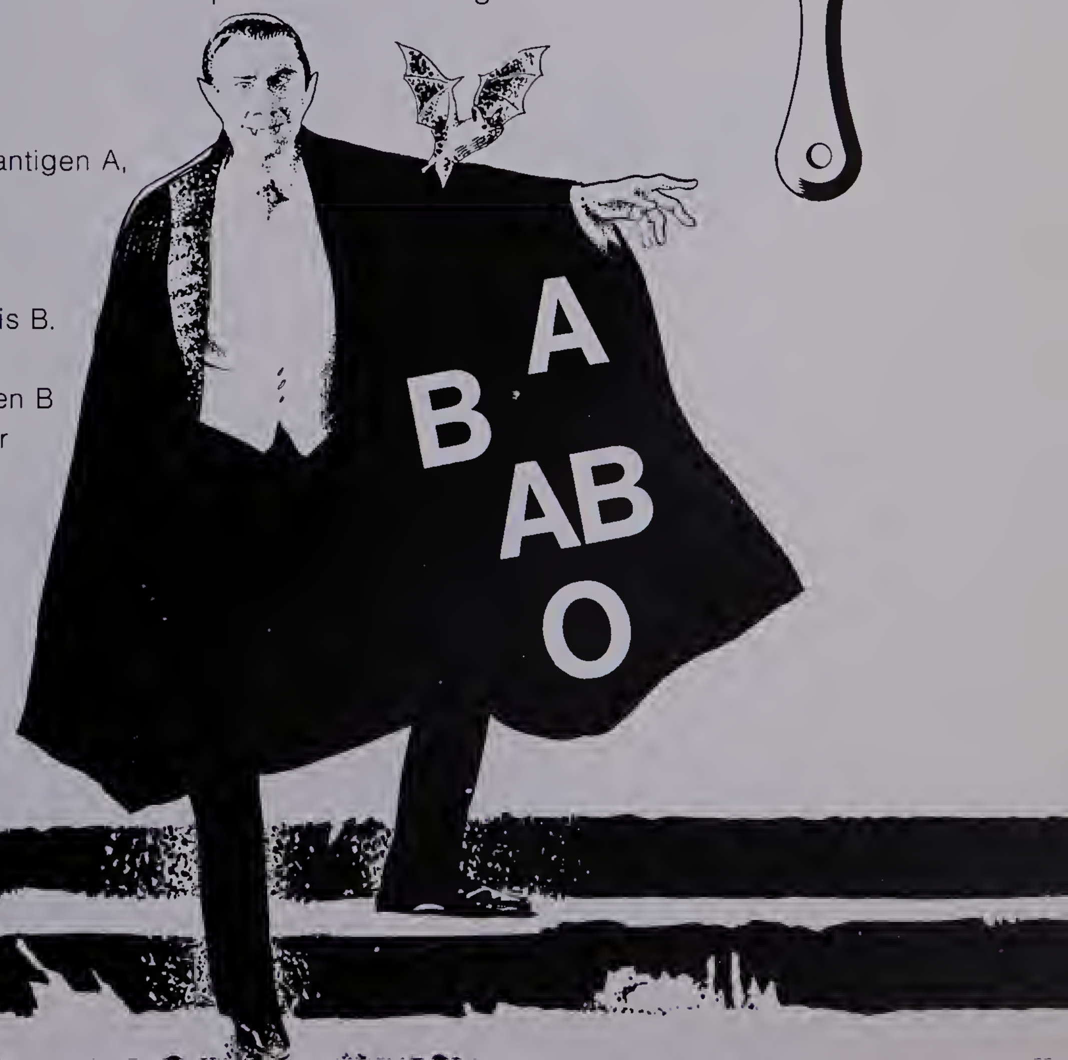
Blood type is determined by the presence or absence of two *antigens* (ANT-i-jens) or substances in the red blood cells. They are antigen A and antigen B. The body's ability to produce antigens is a trait that is inherited. One gene controls the production of antigen A; one controls the production of antigen B.

If your blood cells contain antigen A, your blood type is A.

If your blood cells contain antigen B, your blood type is B.

If both antigen A and antigen B are in your blood cells, your blood type is AB.

If neither of these antigens are in your blood cells, your blood type is O.



13–1. How many genes control the production of antigens for type AB blood?

Blood contains a substance or serum that causes it to react with certain blood antigens. For instance, if you have blood type A, your blood has anti-B serum. The serum reacts with antigen B. Likewise, type B blood has anti-A serum. It reacts with antigen A. The anti-A serum is inherited with antigen B; the anti-B serum is inherited with antigen A.

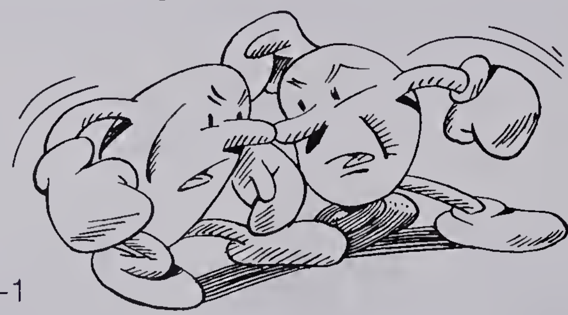


Figure 13–1

13–2. What blood antigen does anti-A serum react with?

13–3. Do you think there are genes for anti-A and anti-B serums? Why?

The reaction that occurs between an antigen and an anti-serum is a clumping or sticking together of blood cells (Figure 13–2). This clumping is easy to observe. In fact, blood is typed by the way it clumps.

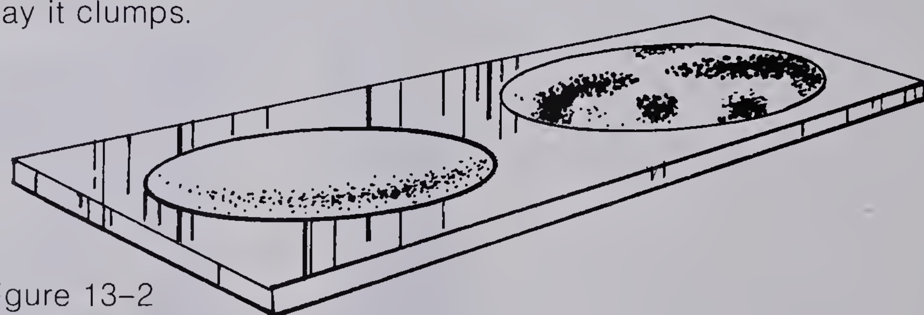


Figure 13–2

Do you want to type your own blood? If you do, you will have to prick your finger to get a few drops of blood. Your school may require that you get permission from a parent or guardian to do this. So check with your teacher before you start. If you are going to type your blood, you will need these items:

- grease pencil
- clean slide
- anti-A serum
- anti-B serum
- medicine droppers, 2
- isopropyl alcohol
- sterile cotton
- wrapped disposable lancet
- toothpick

IMPORTANT: Read through all the steps before you begin.

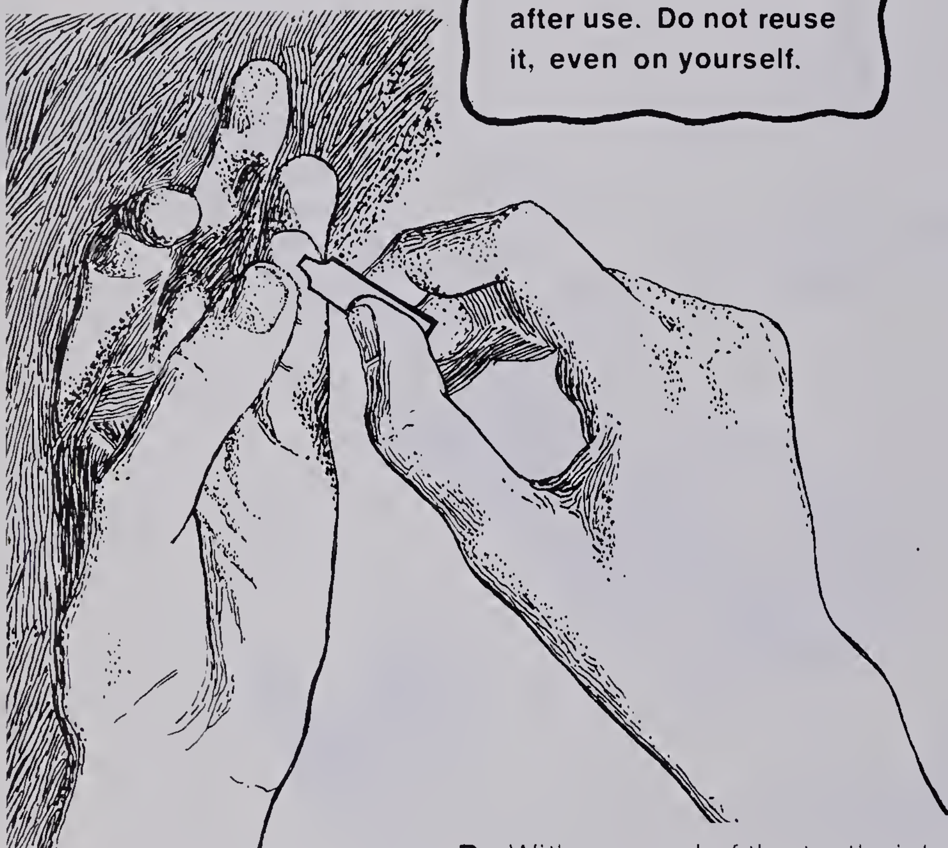
A. With the grease pencil, draw a line separating the slide in half. Mark one side *anti-A*, and the other side *anti-B*. Then use a medicine dropper to place one drop of the anti-A serum on the anti-A side of the slide. Use the other medicine dropper to place one drop of anti-B serum on the anti-B side. These serums are from the plasma or liquid portion of human blood.

B. Pour isopropyl (eye-sa-PRO-pil) alcohol on some cotton. Clean your little finger thoroughly with alcohol.

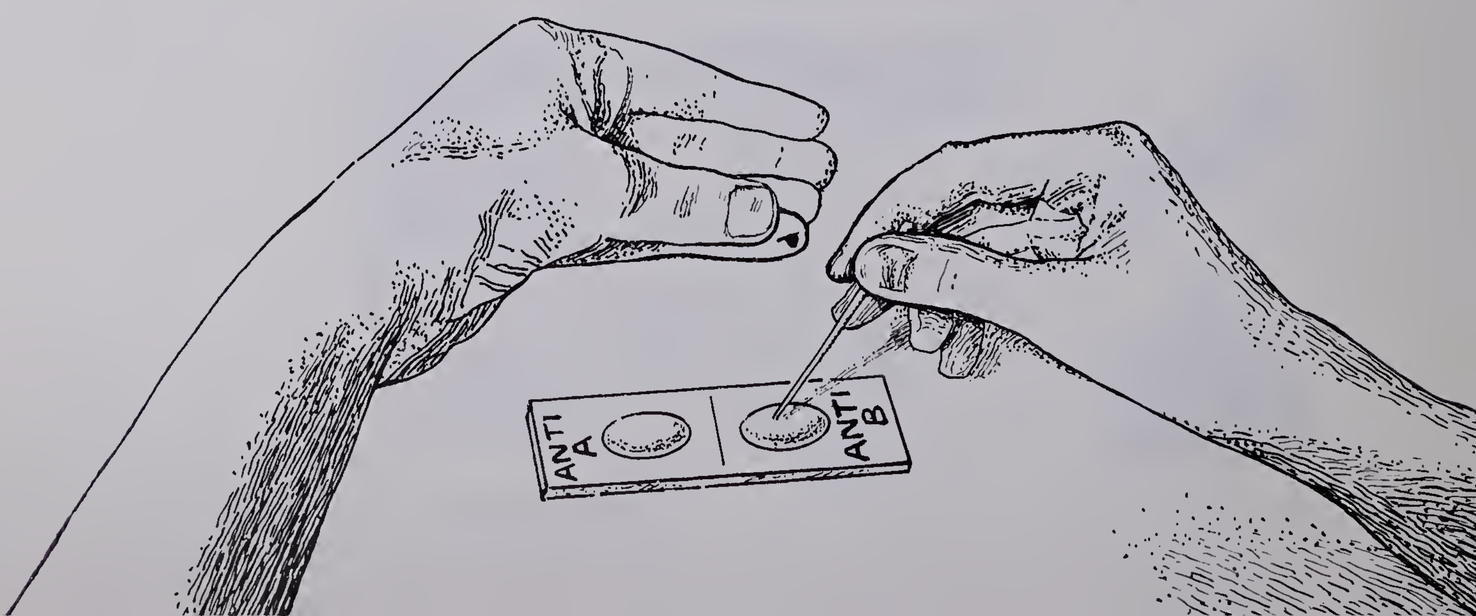
C. Use only an individually wrapped sterile lancet to prick your finger. Do not use any other object. Press the tip of your small finger with the thumb of the same hand. Holding the lancet firmly, quickly prick the tip of your finger.

CAUTION

Throw the lancet away after use. Do not reuse it, even on yourself.

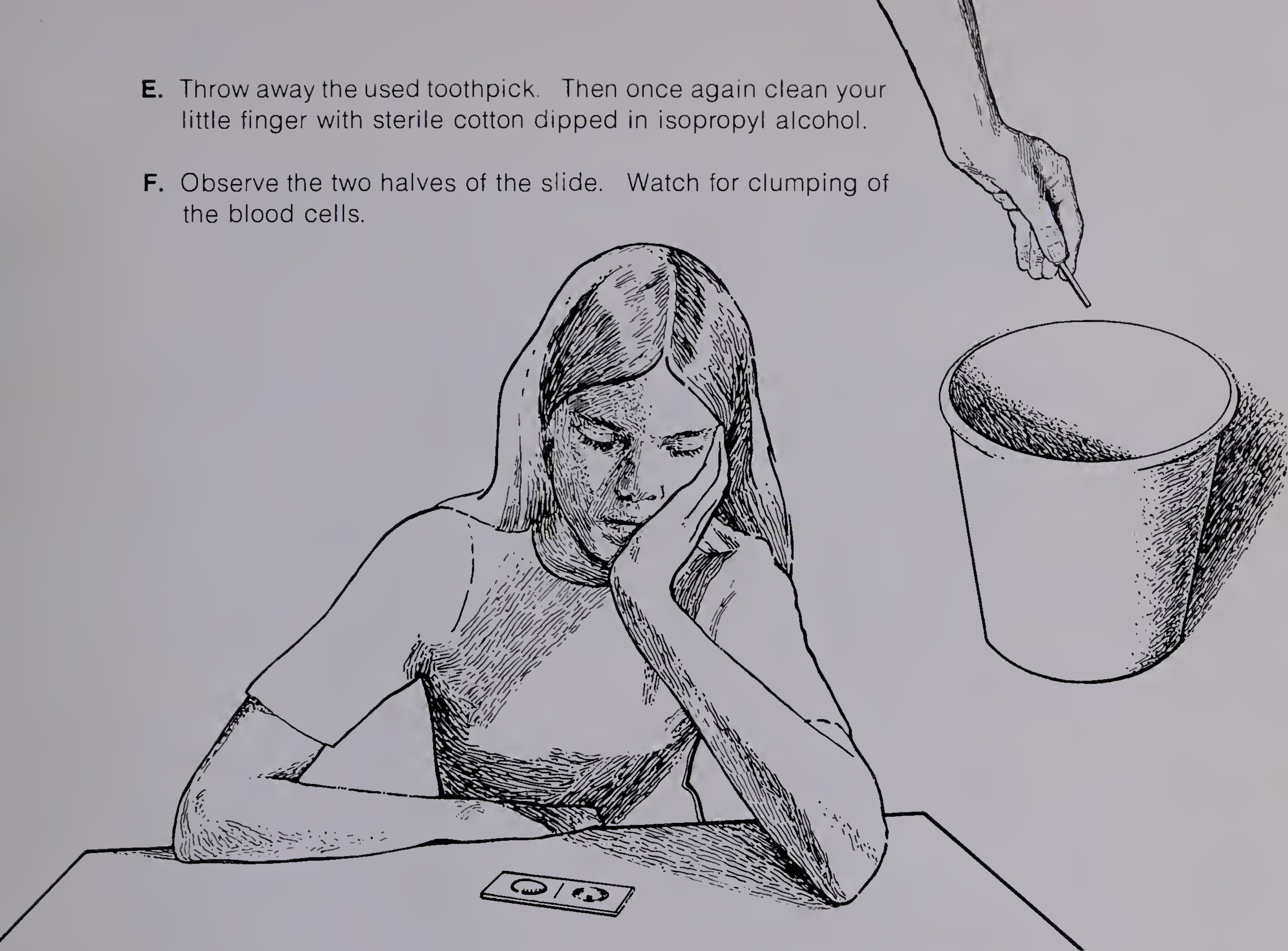


D. With one end of the toothpick, transfer a drop of blood to the anti-A serum on the slide. Stir the drops together. Use the *other end* of the toothpick and transfer a drop of blood to the anti-B serum on the slide. Stir the drops together.



E. Throw away the used toothpick. Then once again clean your little finger with sterile cotton dipped in isopropyl alcohol.

F. Observe the two halves of the slide. Watch for clumping of the blood cells.



✔ 13–4. Was there any clumping of blood cells on either side of the slide? If yes, on which side?

✔ 13–5. If your blood clumps in the anti-A serum only, what antigen is in your blood?

✔ 13–6. If your blood clumps in the anti-B serum only, what antigen is in your blood?

✔ 13–7. If your blood clumps in both the anti-A and anti-B serums, what antigens are in your blood?

✔ 13–8. If your blood does not clump in either serum, what antigens are in your blood?

If you had difficulty answering the last four questions, you may need help in typing your blood.

✔ 13-9. According to your investigations, what is your blood type?

✔ 13-10. List any anti-serums that are present in your blood.

The table in Figure 13-3 shows some characteristics of each blood type.

BLOOD CHARACTERISTICS

BLOOD TYPE	ANTIGEN	SERUM	BLOOD TYPE IT CAN RECEIVE WITHOUT CLUMPING
A	A	anti-B	A, O
B	B	anti-A	B, O
AB	AB	none	A, B, AB, O
O	none	anti-B and anti-A	O

Figure 13-3

Notice that type O blood has no antigens; type AB blood has no anti-serums.

In the United States, about 44% of the people have type O blood, about 37% have type A, about 13% have type B, and about 6% have type AB. This information is especially important for storing blood in blood banks. Ideally, a blood bank should store blood types according to these percentages.

✔ 13-11. Explain why it is not possible for type AB blood to have either anti-B serum or anti-A serum.

To be absolutely sure of your blood type and the serums it contains, have a skilled person type your blood. This is always done before a blood transfusion. If blood can clump on a slide, it can also clump in your blood vessels during a transfusion!

★ **13-12. Why is it important to know a blood type before a transfusion is given?**

There are many other antigens in the blood besides antigens A and B. In fact, scientists today estimate that there are over eight million possible combinations of antigens in human blood!

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